U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

TRECOM TECHNICAL REPORT 64-15

PARAMETRIC INVESTIGATION OF THE AERODYNAMIC AND AEROELASTIC CHARACTERISTICS OF ARTICULATED AND RIGID (HINGELESS) HELICOPTER ROTOR SYSTEMS

Task 1D121401A14211
(Formerly Task 9R38-11-009-11)
Contract DA 44-177-TC-831

April 1964

prepared by:

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Stratford, Connecticut

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This report has been reviewed by the U. S. Army Transportation Research Command and is considered to be technically sound. The report is published for the exchange of information and stimulation of ideas.

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SER-50359

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for

U. S. Army Transportation Research Command
Fort Eustis, Virginia

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FOREWORD

This program was sponsored by the U. S. Army Transportation Research Command, Fort Eustis, Virginia, and administered by Mr. James McHugh.

The aeroelastic investigation was carried out at the Sikorsky Aircraft Division, United Aircraft Corporation, under Messrs. E. R. Wood, K. D. Hilzinger and A. C. Buffalano during the period June 1962 through October 1963. Mr. F. A. Rizzo was responsible for coordinating blade designs and processing data for over 500 flight conditions considered in the investigation. Miss Elizabeth A. O'Connor developed the extensive digital computer program required for the fully coupled blade dynamic analysis.

Guidance and helpful criticism were received from Messrs. W. Gerstenberger, E. S. Carter, K. C. Mard, and D. S. Jenney, all of Sikorsky Aircraft. Others assisting in the program from Sikorsky include Messrs. R. M. Kee and W. D. Miklus (Blade Design), J. R. Olson (Aerodynamics), J. M. Moreno and J. Laufer (Computer Technology).

Appreciation is also due Mr. J. Yeates, U.S. Army Transportation Research Command; Messrs. R. White, F. DuWaldt and R. Piziali, Cornell Aeronautical Laboratory, Inc.; and Mr. I. Culver, Lockheed-California Company, for guidance during the program.

ABSTRACT

This report presents results of an aeroelastic investigation to explore effects of parametric variations on blade stresses and performance of rigid (hingeless) and articulated helicopter rotor systems. The analysis considers the high-speed, steady-state flight condition and takes into account the fully coupled flatwise-edgewise-torsional response of the rotor blades. Substantiation for the method is based upon correlation studies with flight test data from the Lockheed CL-475 rigid rotor helicopter and Sikorsky's S-58 and S-61 articulated rotor helicopters. The study has been limited solely to steady-state flight conditions in which control, fuselage attitude and c.g. have been selected to produce no one-per-rev flapping. It should not be assumed that these flight conditions or the parameters studied are necessarily those most critical to the operation of a rigid or articulated rotor helicopter.

Calculated performance and one-half peak-to-peak flatwise stresses are shown to give good agreement with flight-measured values at higher airspeeds. In the investigation, it is found that blade twist is a significant variable for control of blade vibratory stresses and rotor performance. The sensitivity of rigid rotor flatwise and edgewise stresses to change in design of the blade root region is explored. Studies on variation of blade stiffness indicate that outboard blade stiffening is detrimental (on a moment basis) for an articulated blade, whereas inboard stiffening is detrimental for a rigid blade. For compound helicopters, selection of rotor rpm is found to require an important compromise between blade stress and power.

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TABLES

SYMBOLS

A	blade spar cross section area
A_1	lateral cyclic pitch
B_1	longitudinal cyclic pitch
b	number of blades
C_D	section drag coefficient
C_L	section lift coefficient
C_M	section pitching moment
$C_{(r)}$	blade chord at radius r
C_T	thrust coefficient $T/\pi R^2 \rho (\Omega R)^2$
D/C	ratio of section thickness to section chord
$\frac{dL}{dr}(r\psi)$	blade loading per unit length at azimuth ψ and radius r
E	Young's modulus
gw	aircraft gross weight
I_{xx}	blade spar flatwise area moment of inertia
I_{yy}	blade spar edgewise area moment of inertia
L/C	ratio of spar chord to blade section chord
M	Mach number
M_V	half peak-to-peak bending moment
M_{xx}	rolling moment at center of rotor head in fixed co-ordinate system
M_{yy}	pitching moment at center of rotor head in fixed co-ordinate system

M_{zz}	yawing moment at center of rotor head in fixed coordinate system
R	rotor radius
r	radius to local blade station
S_x	fore and aft shear at center of rotor head in fixed coordinate system
S_y	lateral shear at center of rotor head in fixed coordinate system
S_z	vertical shear at center of rotor head in fixed coordinate system
T	rotor thrust
t/c	ratio of spar mean wall thickness to section chord
V	aircraft forward flight speed
X	fore and aft displacement at center of rotor head in fixed coordinate system
Y	lateral displacement at center of rotor head in fixed coordinate system
$y, \frac{\partial^2 y}{\partial x^2}$	bending curvature
y_v	half peak-to-peak bending curvature
Z	vertical displacement at center of rotor head in fixed coordinate system
α	section angle of attack
$\beta_{T(r)}$	blade angle of twist at radius r referenced to zero at .7R
θ_F	pitching displacement at center of rotor head in fixed coordinate system
$\theta_{.7R}$	collective angle as measured at .7R
$\theta_{(\psi)}$	blade impressed control angle at azimuth ψ

ρ	mass density of air
σ	rotor solidity $bc/\pi R$
ϕ	inflow angle at blade element
ϕ_F	rolling displacement at center of rotor head in fixed coordinate system
ψ	blade azimuth angle, measured positive in the direction of rotation and referenced to zero at the blade full aft position
ψ	yawing displacement at center of rotor head in fixed coordinate system
Ω	rotor angular velocity

SUMMARY

Presented are results of an aeroelastic investigation to explore effects of flight, rotor, and blade parameters on blade stresses and performance of articulated and rigid (hingeless) rotor systems in high-speed flight. Variations in blade planform and twist, rotor lift and propulsive force, blade stiffness and mass distribution are investigated for helicopters and compound helicopters at several gross weights for speeds from 150 to 300 knots. The analysis takes into account the fully coupled flatwise-edgewise-torsional response of the rotor blades. Substantiation for the method is based upon correlation studies with flight test data from the Lockheed CL-475 rigid rotor helicopter and Sikorsky's S-58 and S-61 articulated helicopters.

In all, 504 data points are considered in the investigation, which treats the steady-state flight condition. A few of the noteworthy results explained are: (1) the trends of blade twist as a significant variable for control of blade stresses and rotor performance; (2) the sensitivity of rigid rotor flatwise and edgewise stresses to change in design of the blade root region; and (3) the effects of blade weights as a means to reduce blade vibratory stresses for both rotor systems.

Extension of this work to critical consideration of transient and other flight conditions is discussed under "Recommendations". It must be emphasized that the study reported herein has been limited solely to steady-state conditions in which control, fuselage attitude and c. g. have been selected to produce no one-per-rev flapping. Because of the obviously critical effect of flapping on hingeless rotor root bending moments and because transient manuever, c. g. variations and off-design trim attitudes inevetably must produce flapping, this area is clearly one for further investigation.

CONCLUSIONS

Results are presented from an analytical program to explore effects of parametric variations on blade stresses and performance of rigid* and articulated rotor systems. The analysis considers the high-speed, steady-state flight condition and takes into account the fully coupled flatwise-edgewise-torsional response of the rotor blades. For the studies, constant inflow is assumed.

The rigid or hingeless rotor designs were configured to criteria established by the Lockheed-California Company (see Section 4). For uniform planform blades investigated, these criteria resulted in "rigid" designs which were equivalent to articulated rotors with from 15% to 30% flapping offset, where equivalence was based upon the frequency of the first flapping mode.

A. CORRELATION

Calculated performance and one-half peak-to-peak flatwise stresses are shown to give good agreement with flight measured values for both rigid and articulated rotor helicopters at higher airspeeds. As reported in References (1) and (2), results indicate that one-half peak-to-peak blade stress may be accurately calculated at high airspeeds without variable induced velocity. For low airspeeds, however (below 100 knots), variable inflow is required to calculate one-half peak-to-peak bending stresses. Also, variable inflow effects are required to accurately predict higher frequency airloads and blade stresses at all airspeeds. For compound helicopters, where the rotor angle-of-attack is near zero, the validity of constant inflow for blade stress calculations is open to question. Final evaluation will depend upon test data for this type of aircraft.

B. PARAMETRIC TRENDS

Conclusions which may be drawn from results of the parametric investigation include:

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* As used within this report, the term "rigid" refers to a rotor system without flapping or lag hinges. In the strictest sense, this term is misleading since the blade root region for such a rotor system has flexibility contributed by both bearings and blade spar.

(1) Blade twist was found to be a significant variable for control of blade stresses and rotor performance. Increased negative twist acts to unload the retreating and load the advancing blade. Due to the helicopter's pitch-trim requirements, the advancing blade must carry the increased load on the inboard panels rather than the more efficient outboard panels. The resulting one-per-rev load dissymmetry is the aerodynamic cause of increased blade vibratory stress. This means, on a vibratory stress basis, that the advancing blade and not the retreating blade becomes critical for large negative twist. Results of calculations for planform-twist variation indicate a rapid rise in vibratory bending moments with increase in blade twist for rigid and articulated rotor systems. Small values of negative twist resulted in minimum blade stress, while the optimum power-twist tradeoff required larger values of negative twist. Also, the power-twist gradient was noted to be much lower than the stress-twist gradient. The value of blade twist for minimum vibratory stress was noted to be relatively independent of the aircraft's mission, whereas power minimums showed noticeable variation. For the aircraft considered, blade twist to minimize stress was found to be in the region of +2 degrees to -2 degrees. Optimum power for helicopters was found to be in the region of -8 degree twist; for the jet compounds, in the region of -4 degrees; and for the winged compounds, in the region of 0 degree. For winged compounds, variation in power with change in blade twist was found to be small.

(2) Studies on variation of blade stiffness indicated that outboard blade stiffening was detrimental (on a moment basis) for an articulated blade, whereas inboard stiffening was detrimental for a rigid blade. Blade stiffening effects may or may not reduce blade stress depending upon the

tradeoff between bending moment and section modulus at the critical blade station.

(3) Addition of blade weights can be beneficial. Reduction in vibratory bending moments was observed for both rigid and articulated blades by introducing a concentrated weight at the blade tip. For the 33,000-pound helicopter considered, greatest reduction was achieved for both systems with the first 10 pounds added; there was less reduction thereafter. Tapered blade mass distribution did not appear to offer any significant advantage.

(4) Studies of compound helicopter designs revealed several important compromises. Reduced rotor speed is required to alleviate effects of compressibility and to lower overall power requirements. However, a more demanding condition for rotor speed may be blade life and reliability. Here, accurate control of rotor rpm is important due to rapid changes in stress and power with rpm fluctuations. This means that gust and maneuver conditions may govern compound helicopter design.

(5) For compound helicopters, autorotation of the rotor was found to be a poor flight condition based on blade stress and total power required. Setting the rotor near zero angle-of-attack with the rotor providing only lift, and using external propulsive force to overcome rotor drag, resulted in a satisfactory flight condition. Rotor angle-of-attack with respect to the air stream may be controlled by cyclic pitch and power input to the shaft.

(6) Results of rotor hub impedance studies indicated that blade-fuselage coupling may be important in predicting higher harmonic blade response and associated fuselage response.

(7) Inclusion of torsion in the blade analysis did not essentially alter the character of the azimuth-wise distribution of flatwise bending moments, but did yield higher vibratory values than were predicted when torsion was not included. With torsion added, control loads could be calculated. Here, with increase in airspeed a buildup in magnitude of calculated control loads was observed. Also noted was an increase in their higher harmonic content.

C. DESIGN CONSIDERATIONS

Available to the blade designer is both a selection of material and a range of section moduli to meet stress requirements. With this freedom it is possible to bring about significant changes in resulting stress patterns. For this reason, results in this report are compared on a bending moment rather than stress basis. This, of course, makes comparison susceptible to size effect, but it properly reflects blade mass and stiffness distribution, yet avoids the open question of the many possible section moduli which can be selected to carry imposed bending moments.

Rigid rotor flatwise and edgewise vibratory moments were observed to be sensitive to design of the blade root region. For this rotor system, properly designed flexibility gave a root restraint which was between a theoretical rigid and hinged condition. For chordwise design of rigid blades, tuning was especially important due to high amplication of edgewise moments as the inplane frequency approached one-per-rev. Lockheed criteria (See Section 4) for high aspect ratio blades (A. R.$>$18) specifies flexible design of the root to place the first edgewise mode at about 0.65Ω. Note that this rotor is brought up to operating speed through the one-per-rev range. For these blades, design consideration should be given to adequate control of edgewise stress during run-up.

For the articulated blade, maximum vibratory moments generally occurred at the two-thirds blade radius, while location of maximum centrifugal stress was at the blade root. The rigid blade did not have this separation of design points. Here, both maximum steady and maximum vibratory values occurred at the blade root. To control combined stresses the rigid rotor designer must weigh area requirements (to carry steady centrifugal loads) and stiffness requirements (for blade dynamic response) in the blade root region.

Blade stiffness changes were found to be significant for both rotor systems in the region of maximum vibratory moment. Adding material to the blade in this region may or may not reduce stress depending upon the tradeoff between bending moment and section modulus. For section moduli considered in this study, an increase in vibratory stresses was generally noted with increased stiffness.

RECOMMENDATIONS

While this study was principally concerned with blade parametric variations in high-speed, steady-state flight, it should not be assumed that these flight conditions and parameters are necessarily those most critical to the operation of an articulated or rigid rotor design. Serious consideration should also be given to other areas which are outside the scope of this study. These include: (1) effects of gusts and maneuver loads on blade stresses for both rotor systems; (2) stability and control of each rotor system in high-speed flight and associated blade stresses; and (3) for compound helicopters, effects of rotor angle-of-attack on stability and stresses for both rotor systems, and the significance of variable inflow when the rotor is near zero angle-of-attack.

Although not covered within the scope of this report, a preliminary study was made of effects of fuselage c. g. shifts on blade stresses. Early results indicated that rigid blade stresses were more sensitive to fore and aft shifts of the fuselage c. g. than corresponding articulated blade stresses. Fore and aft c. g. shifts appeared to induce a one-per-rev load dissymmetry, which the rigid rotor responded to by bending, while the articulated rotor responded in flapping. Effects of longitudinal and lateral c. g. shifts on associated blade stresses should be explored in more detail for each rotor system.

At particular airspeeds, it appeared possible to obtain the effect of planform taper on aerodynamic loads by proper choice of twist on a 1:1 taper blade. This effect should be explored in more detail due to the relative simplicity of changing twist when compared to changing blade planform.

1. INTRODUCTION

Design of helicopters and compound air vehicles for higher airspeeds requires greater knowledge of rotary-wing dynamics and performance than is presently available from published analyses and investigations. For fuller understanding of advanced flight regimes, an analytical program was required, which would explore effects of forward speed, blade planform, blade twist, rotor lift and propulsive force, blade stiffness and mass distribution, rotor tip speed and altitude on the blade motions, blade stresses, and performance of articulated and rigid rotor systems.

To provide this information, Sikorsky Aircraft last year undertook a study for the U. S. Army Transportation Research Command. This report gives results of that study. The work was carried out by a joint effort of the company's Aerodynamic, Blade Design, and Dynamics Sections. Three well developed analytical programs were used in the study: (1) an Advanced Performance Analysis, which was used to determine the basic rotor parameters to be studied; (2) a Horvay-type Blade Design Analysis, which has been responsible for Sikorsky's present-day successful blade designs; and (3) a Coupled Blade Flatwise-Edgewise-Torsional Aeroelastic Analysis, which yields the full spectrum of blade dynamic information. The aeroelastic analysis is general and well suited for studies of a wide range of helicopters and VTOL-type aircraft with rotor blade and propellers of all types. As will be shown in the report, good correlation has been achieved with the method for both rigid and articulated rotor systems.

The report which follows treats each phase of the investigation separately. First, the scope of the program is described, and variations in parameters are outlined by means of tables and flow charts. Next, aerodynamic criteria are established from which basic rotor parameters are determined. Blade design criteria are discussed. Based on this, structural characteristics are developed for the sixteen basic rotor systems considered in the program. Also set forth are criteria followed in extrapolating blades of one planform to those of another.

Development of the aeroelastic analysis is presented with reference to two earlier papers which describe the method in greater detail. Included in this section is a discussion of steps taken to check out the digital computer program. Following this, correlation of analysis with flight test data is presented for the Lockheed CL-475 rigid rotor helicopter and Sikorsky's S-58 and S-61 articulated helicopters.

Significant trends resulting from calculations for 504 separate flight conditions comprise the major part and remainder of the report. Wherever possible, efforts have been directed toward explaining trends, as well as presenting them. Included are discussions on such topics as increase in vibratory stress with negative twist, and rotor system power-stress tradeoff at high speeds.

2. SCOPE OF PROGRAM

Included in the overall study are eight basic aircraft. four in the 12,000-pound class and four in the 33,000-pound class. The design configurations are two 150-knot helicopters, two 180-knot helicopters, two 200-knot wingless compounds, and two 250-knot winged compounds. Four planform variations are considered in each case, and blades are taken as both rigid and articulated. Table 2.0 presents a summary of aircraft considered and includes a listing of basic aircraft parameters. Basic parameters were the same for both articulated and rigid rotor (designated -R) designs. Profile and plan view drawings of the eight designs are presented in Figures 2.1 through 2.8. Blade planform variations are given in Figure 2.9. Table 2.1 gives the range of flight conditions treated in the investigation.

Shown in Tables 2.2 through 2.6 are the schedules of calculations performed under the program. Tables 2.7 through 2.9 are flow charts which illustrate the order of calculations. In all, 504 data points were calculated for the patametric investigation.

Given in Appendix A, Figures A-1 through A-8, are fuselage lift and drag curves versus airspeed for the aircraft considered. Helicopter fuselage lift and drag data are presented in Figures A-1 through A-4. Variation of these curves from simple V^2 curves is due to changing body attitude with change in airspeed. Fuselage lift and drag data were similar for both rigid and articulated rotor helicopters performing the same mission.

Fuselage drag data for compound helicopter designs are presented in Figures A-5 through A-8. Here, a simple V^2 relation was used since aircraft attitude would be held substantially constant at higher airspeeds. Details of compound trim conditions are discussed in Section 3.

Criteria by which detailed design of the respective rotor systems was determined are discussed in Sections 3 and 4, which follow. Resulting blade stiffness and mass properties are tabulated in Appendix B, Tables B-1 through B-64. These provided the basic input to the aeroelastic analysis, which is described in References 1 and 2 in detail, and in brief in Section 5 of this report.

Results of the aeroelastic investigation are summarized within this report where plots of pertinent parameters have been made and significant trends noted. Calculations were done on an IBM 7090 digital computer at United Aircraft Corporation's Research Division in East Hartford, Conn. Each of the 504 data points required 5 minutes of computer time. For each data point, the following information was obtained on IBM printout sheets in addition to input data.

1. Cyclic pitch at 36, 10-degree azimuth intervals.

2. Thrust moment about the flapping hinge at 36, 10-degree azimuth intervals.

3. Blade element thrust - 756 values representing the lift on each of 21 blade elements at 36, 10-degree azimuth intervals.

4. Blade element drags - 756 values representing the drag on each of 21 blade elements at 36, 10-degree azimuth intervals.

5. Blade element pitching moments - 756 values representing the pitching moment on each of 21 blade elements at 36, 10-degree azimuth intervals.

6. Blade element thrust - steady plus 7 harmonics in complex form for 21 blade stations.

7. Blade element drag - steady plus 7 harmonics in complex form for 21 blade stations.

8. Blade element pitching moments - steady plus 7 harmonics in complex form for 21 blade stations.

9. Blade dynamic response:

    a. For each of 24 blade stations, 8 responses in complex form, the steady plus seven harmonics of blade response: flatwise amplitudes, moments, shears, and slopes; edgewise amplitudes, moments, shears, and slopes; torques and torsional deflections.

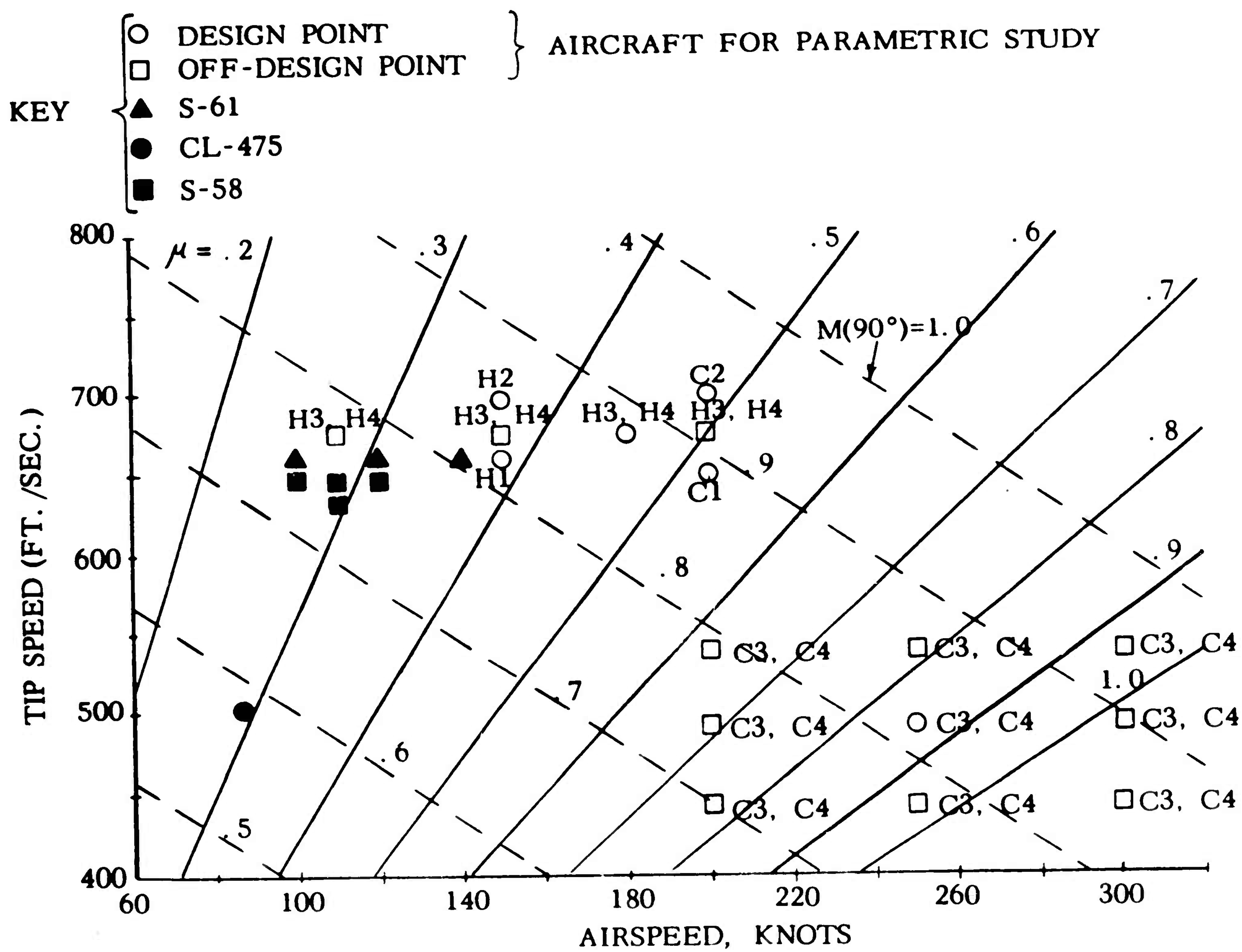
    b. Total response: For each of 21 blade stations at each of 36, 10-degree azimuth intervals: flatwise amplitude, moment, shear, slope, and stress; edgewise amplitude, moment, shear, slope, and stress; torque, torsional deflection, and torsional stress; maximum peak-to-peak flatwise stress, edgewise stress, and torsional stress and radial station at which each occurs.

TABLE 2.0

DESCRIPTION OF AIRCRAFT

AIRCRAFT DESIGNATION	H1 H1-R	H2 H2-R	H3 H3-R	H4 H4-R	C1 C1-R	C2 C2-R	C3 C3-R	C4 C4-R
MISSION GROSS WT. (LBS.)	12000	33000	8700	30000	12000	27000	14000	30000
MISSION V CRUISE (KTS.)	150	150	180	180	200	200	250	250
BLADE RADIUS (FT.)	31	36	28	36	28	36	28	35
ROTOR SPEED (RPM)	203	185	230	179	222	186	168	135
TIP SPEED (FPS)	660	696	675	675	650	700	493	493
NO. OF BLADES	5	6	5	8	6	6	5	4
AIRFOIL SECTION	0012	0012	0012	0012	0012	0012	0012	0012
DESIGN TWIST FOR 1:1 TAPER BLADE (DEG.)	-8	-6	-4	-8	-4	-8	-2	-2
CHORD (IN.)	18.25	23.65	18.25	19.80	18.25	23.65	18.25	36.00
OFFSET (IN.)	12.625	24	12.625	24	12.625	24	12.625	30
PERCENT GROSS WEIGHT CARRIED BY ROTOR	100	100	100	100	96	100	15	15
SOLIDITY	.07804	.1046	.086	.1165	.1045	.1045	.086	.110
C_T/σ	.050	.068	.039	.059	.045	.054	.017	.018

TABLE 2.1
RANGE OF FLIGHT CONDITIONS



Air-craft	Blade Loading (PSF)
Cl-475	41.1
S-58	86.7
S-61	72.2
H1	50.9
H2	77.6
H3	40.9
H4	63.1
C1	45.1
C2	63.5
C3	9.9
C4	10.7

TABLE 2.2

PERFORMANCE SCHEDULE

HELICOPTER

1. Gross Weight : 12,000, 33,000 lb. at 150 kt.
   8,700, 30,000 lb. at 180 kt.
2. Altitude : Sea Level
3. Blade Twist : 0, -4, -8, 16° *(128)
4. Blade Planform : 1:1, 3:1, 1:2, nonlinear
5. Retention : Articulated, Rigid

COMPOUND HELICOPTER

1. Gross Weight : 12,000, 27,000 lb. at 200 kt.
   14,000, 30,000 lb. at 250 kt.
2. Altitude : Sea Level
3. Blade Twist : +4, 0, -4, -8° at 200 kt. (128)
   +2, 0, -2, -4° at 250 kt.
4. Blade Planform : 1:1, 3:1, 1:2, nonlinear
5. Retention : Articulated, Rigid

The following additional variations were investigated for the aircraft indicated, using a 1:1 blade planform and design twist. Each variation is made assuming all other parameters constant at the assumed value of the above study.

a.) Altitude : 5,000, 10,000, 15,000, 20,000 ft. (56)
(All aircraft)

b.) Parasite Drag : 3 variations (44)
(180-knot helicopters at 4 different speeds)

c.) Rotor RPM : 3 variations (44)
(250-knot compounds at 4 different speeds)

* Number of data points.

TABLE 2.3

STIFFNESS SCHEDULE

HELICOPTER

1. Gross Weight : 33,000 lb.

2. Air Speed : 110, 150, 180 kts.

3. Retention : Rigid (all speeds) (15)

   Fully Articulated (all speeds) (15)

   Teetering Rotor Head (150 kts. only) (15)

4. Blade Planform : 1 : 1

5. Blade Twist : Design Value

6. Blade Parameters : All parameters standard configuration except as noted in 7.

7. Stiffness Variations : I/I_0 vs. R

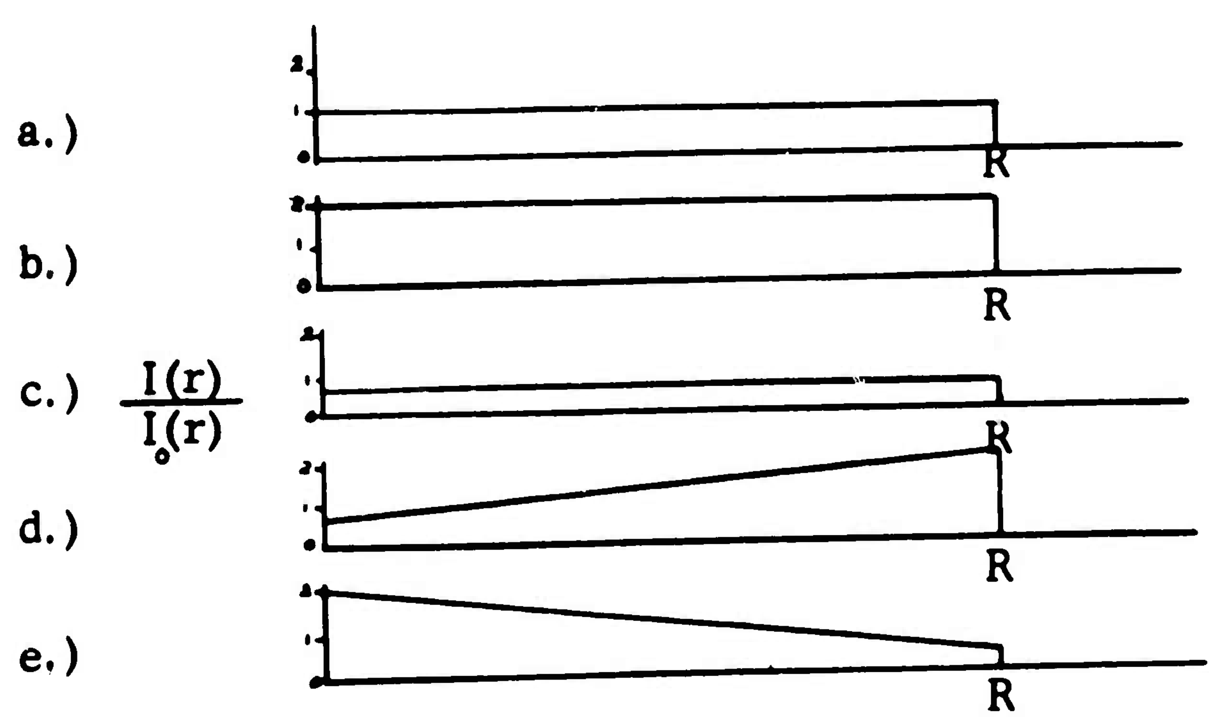


TABLE 2.4

MASS DISTRIBUTION SCHEDULE

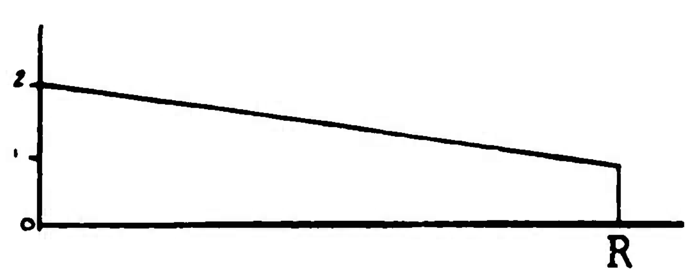
HELICOPTER

1. Gross Weight : 33,000 lb.
2. Air Speed : 150 kt.
3. Retention : a.) Rigid
   b.) Articulated
   c.) Teetering Rotor
4. Blade Parameters : All parameters standard configuration except as noted in 5.
5. Mass Variation :
   a.) Concentrated mass at 5 radial locations (15)

   b.) Two concentrated masses (5 variations in location) (15)

   c.) Single concentrated mass at optimum location (5 variations in mass) (15)

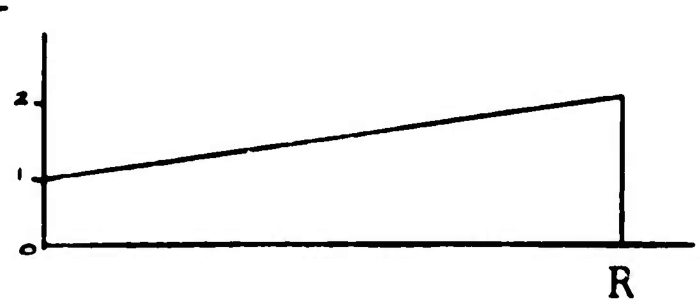
   d.)



(3)

$\frac{m(r)}{m_0(r)}$

   e.)



(3)

TABLE 2.5

ROTOR HEAD IMPEDANCE SCHEDULE

HELICOPTER

1. Gross Weight : 33,000 lb.
2. Air Speed : 150 kt.
3. Planform : 1:1 Design Blade (7)
4. Twist : Design
5. Seven variations in rotor head impedance

BOUNDARY CONDITIONS SCHEDULE

HELICOPTER

1. Gross Weight : 33,000 lb.
2. Air Speed : 150 kt.
3. Planform : 1:1 Design Blade
4. Twist : Design
5. Boundary Conditions :
   - a.) Articulated flatwise, cantilevered edgewise
   - b.) Articulated flatwise, articulated edgewise (3)
   - c.) Cantilevered flatwise, articulated edgewise

TABLE 2.6

ROOT FLEXIBILITY SCHEDULE

HELICOPTER

1. Gross Weight : 33,000 lb.

2. Air Speed : 150 kt.

3. Planform : 1:1 Design Blade

4. Twist : Design

5. Boundary Conditions :

   articulated flatwise - articulated edgewise except as noted in 6.

6. Flexibility Variations :

   a.) Vary flatwise flexibility at root from hinge value to cantilever value in 4 increments (4)

   b.) Vary edgewise flexibility at root from hinge value to cantilever value in 4 increments (4)

   c.) Vary edgewise damping rate through 5 values to simulate lag damper action (5)

TABLE 2.7

HELICOPTER PERFORMANCE SCHEDULE FLOW CHART

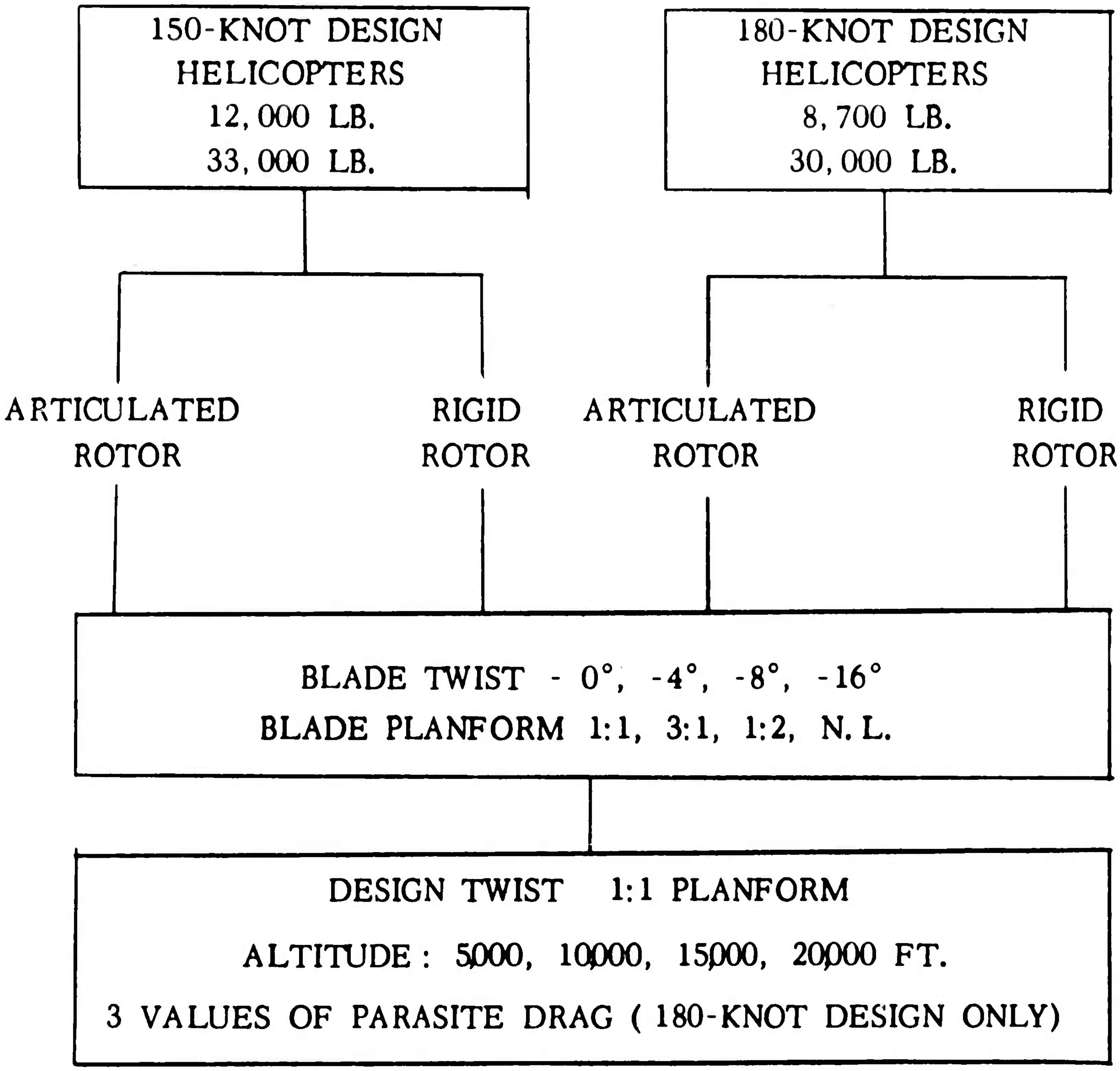


TABLE 2.8

COMPOUND PERFORMANCE SCHEDULE FLOW CHART

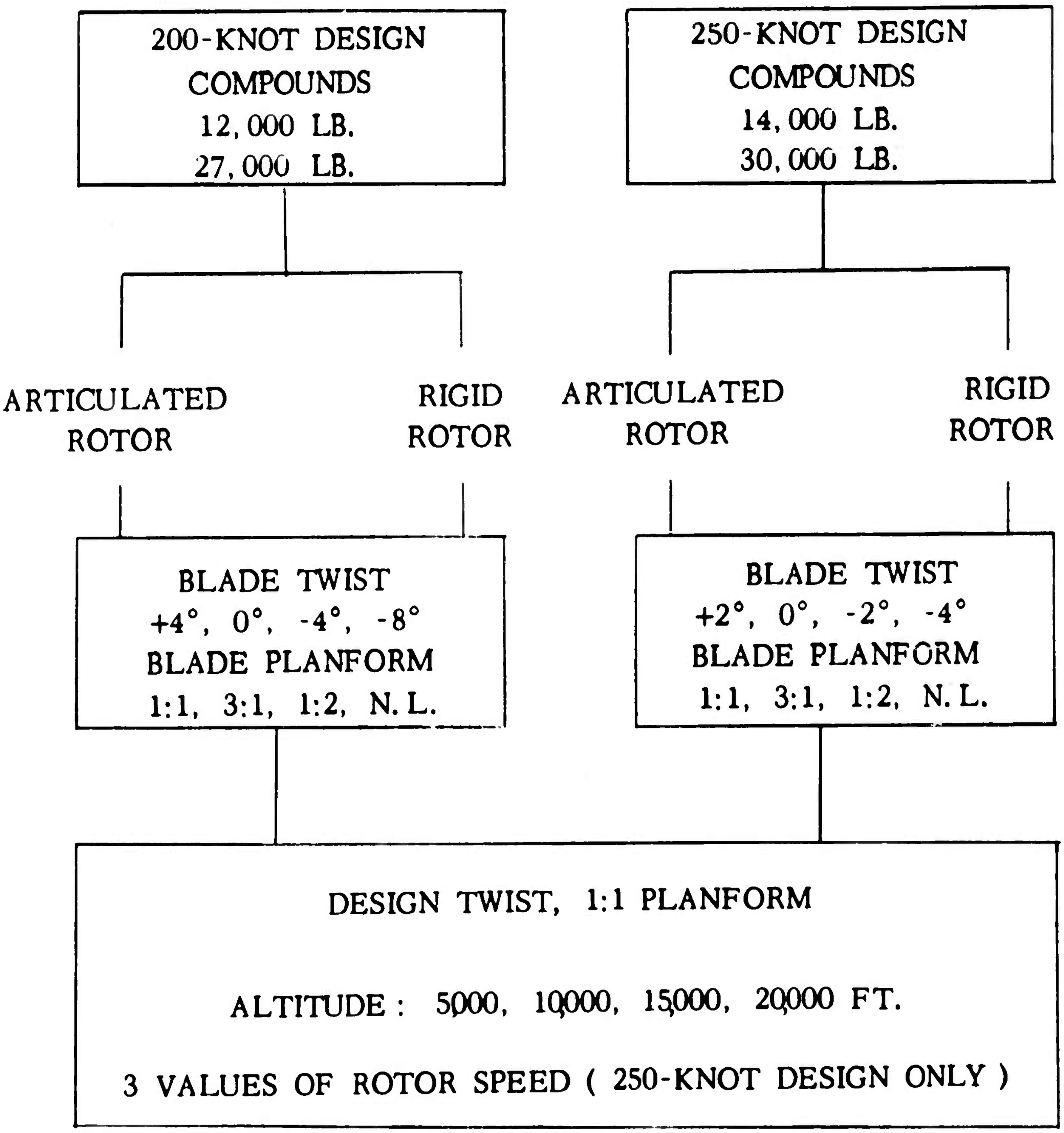
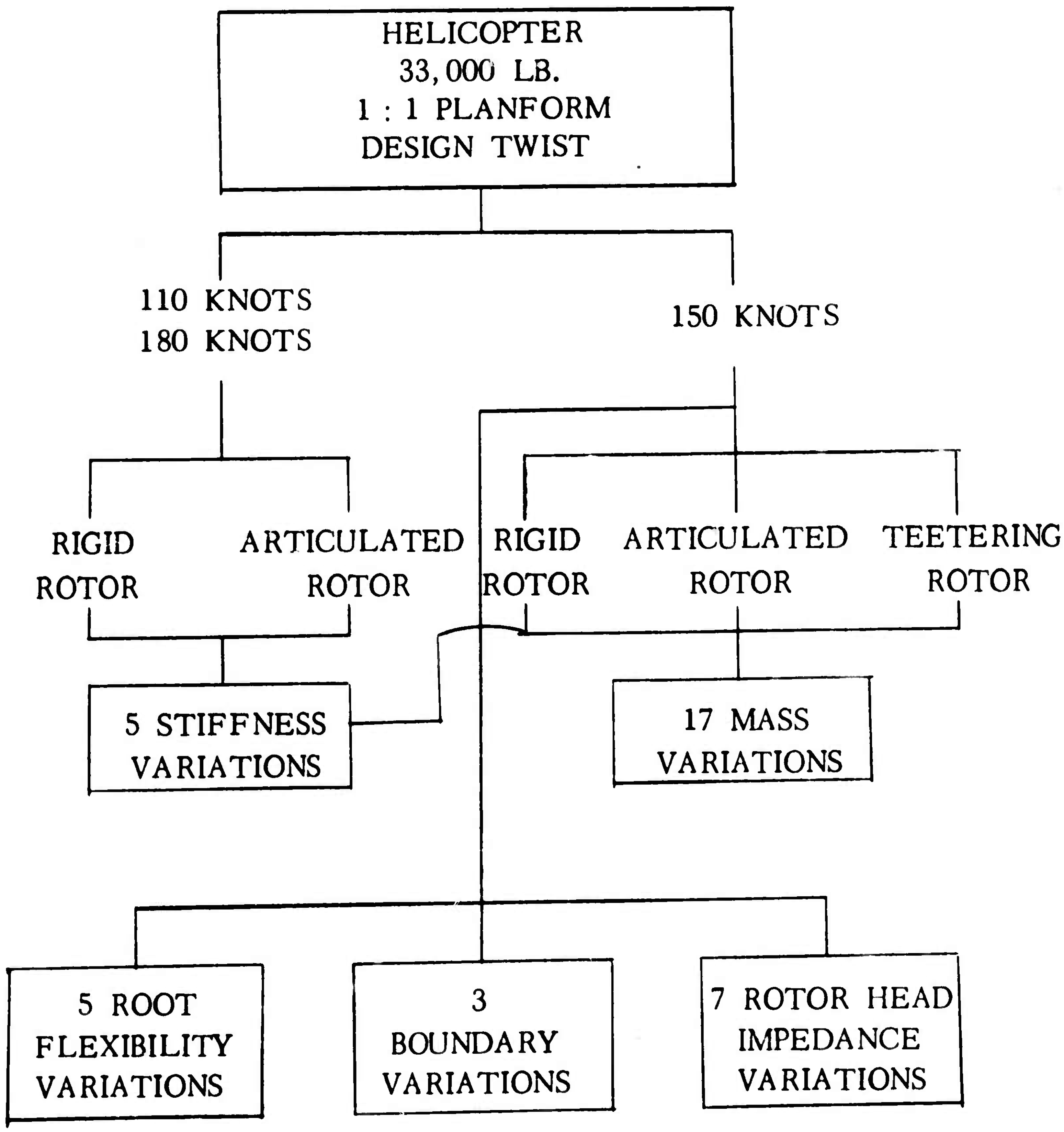


TABLE 2.9

STIFFNESS, MASS AND ROOT SCHEDULE FLOW CHART



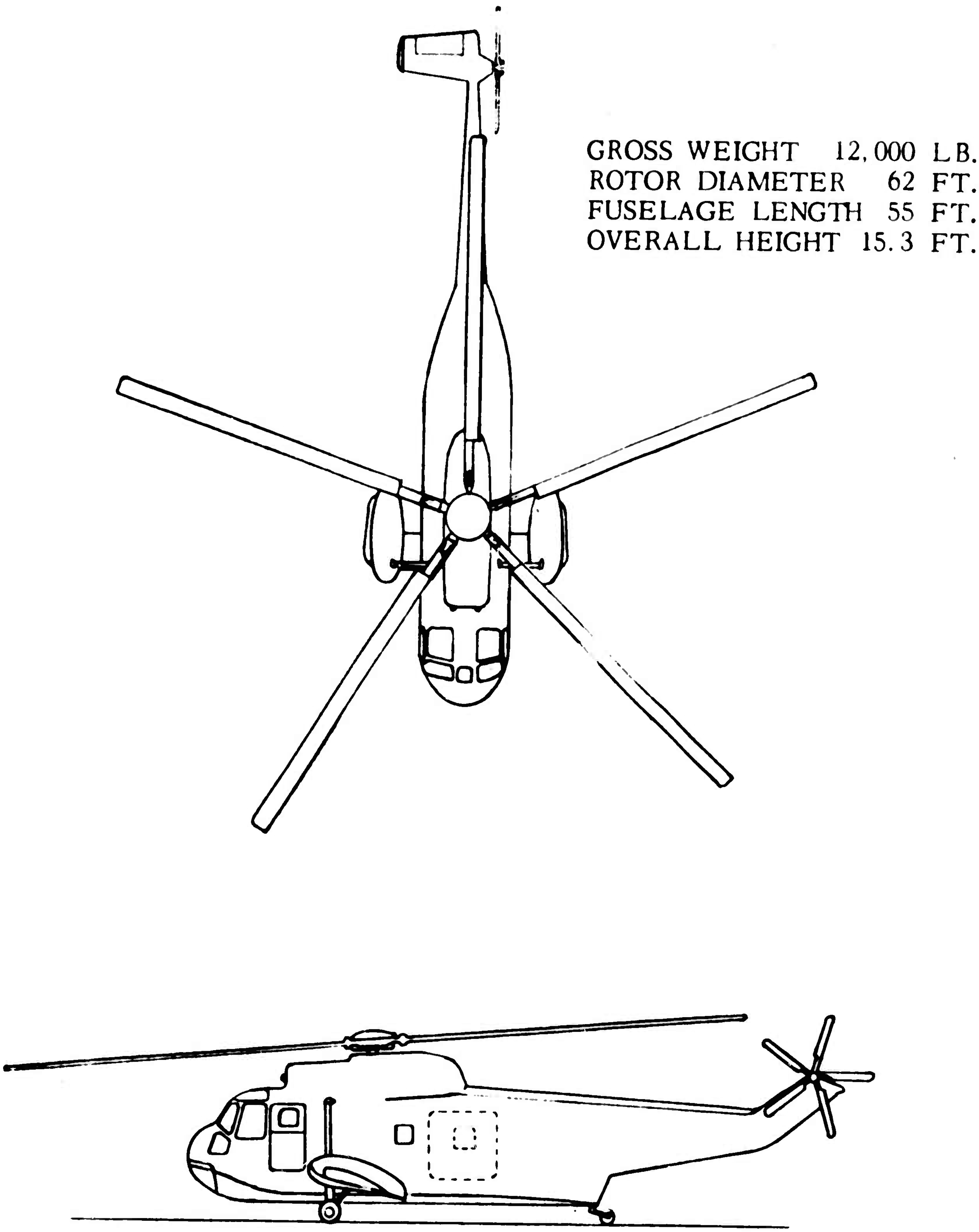


FIG. 2.1 H1 HELICOPTER

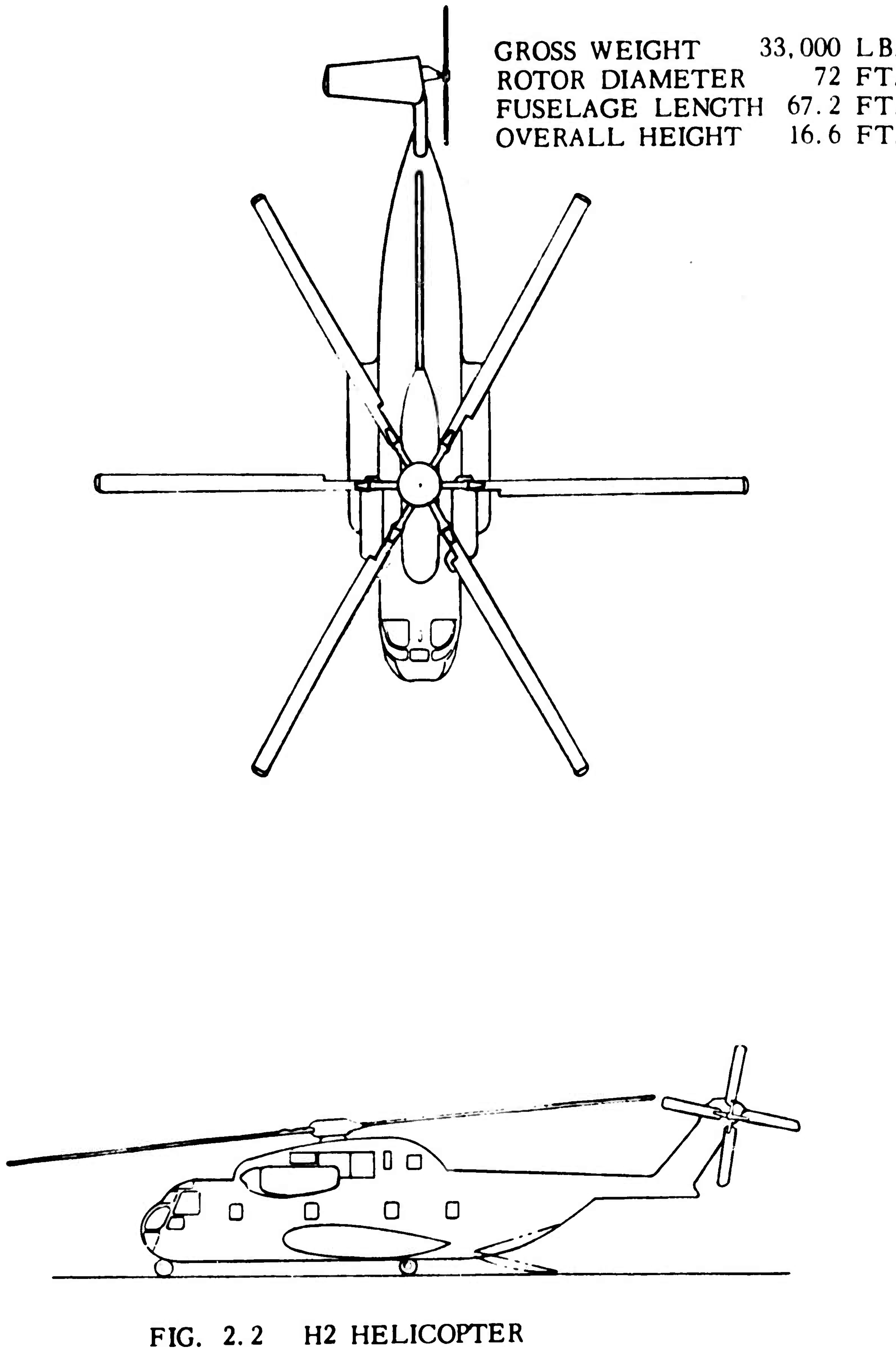


FIG. 2.2 H2 HELICOPTER

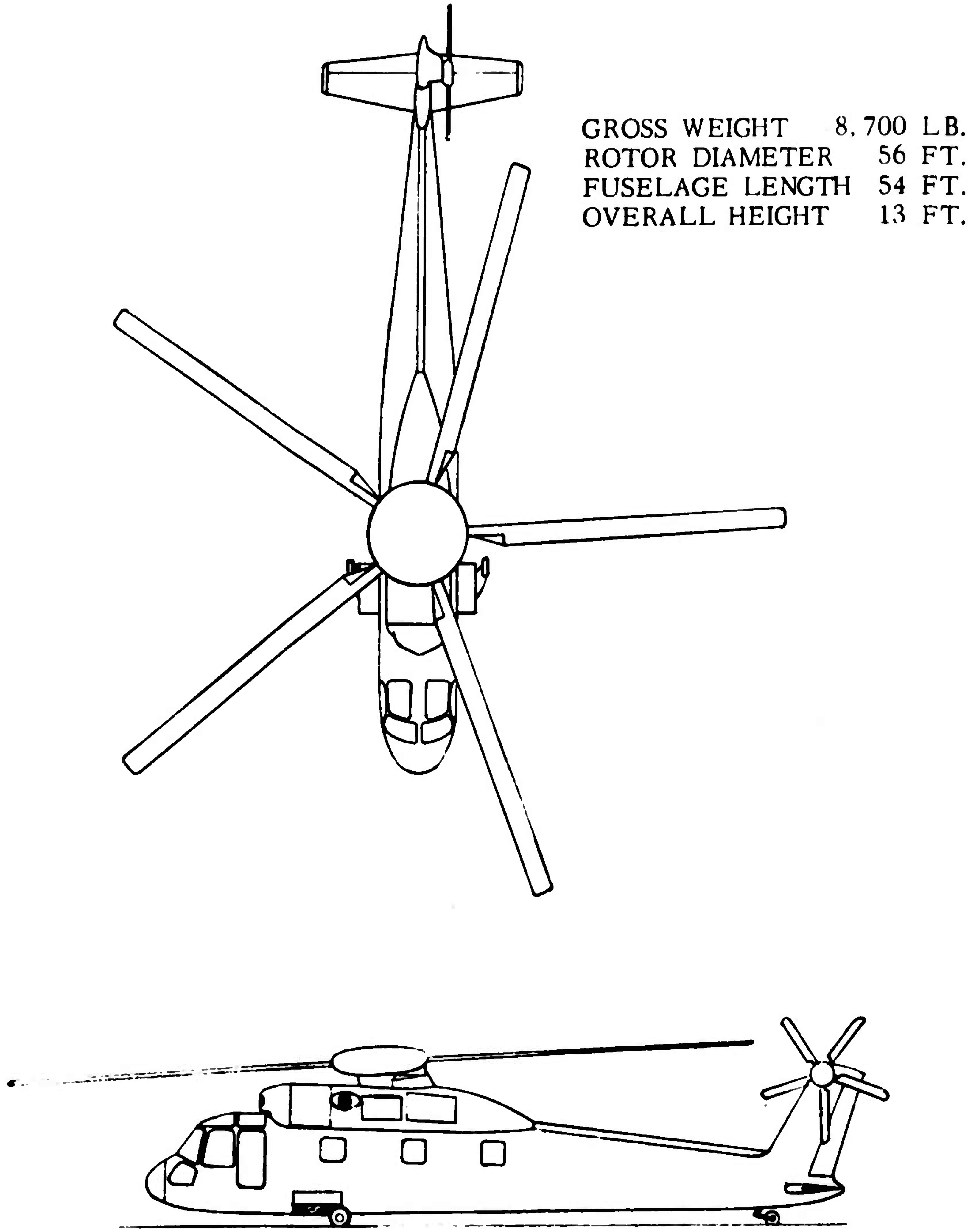


FIG. 2.3 H3 HELICOPTER

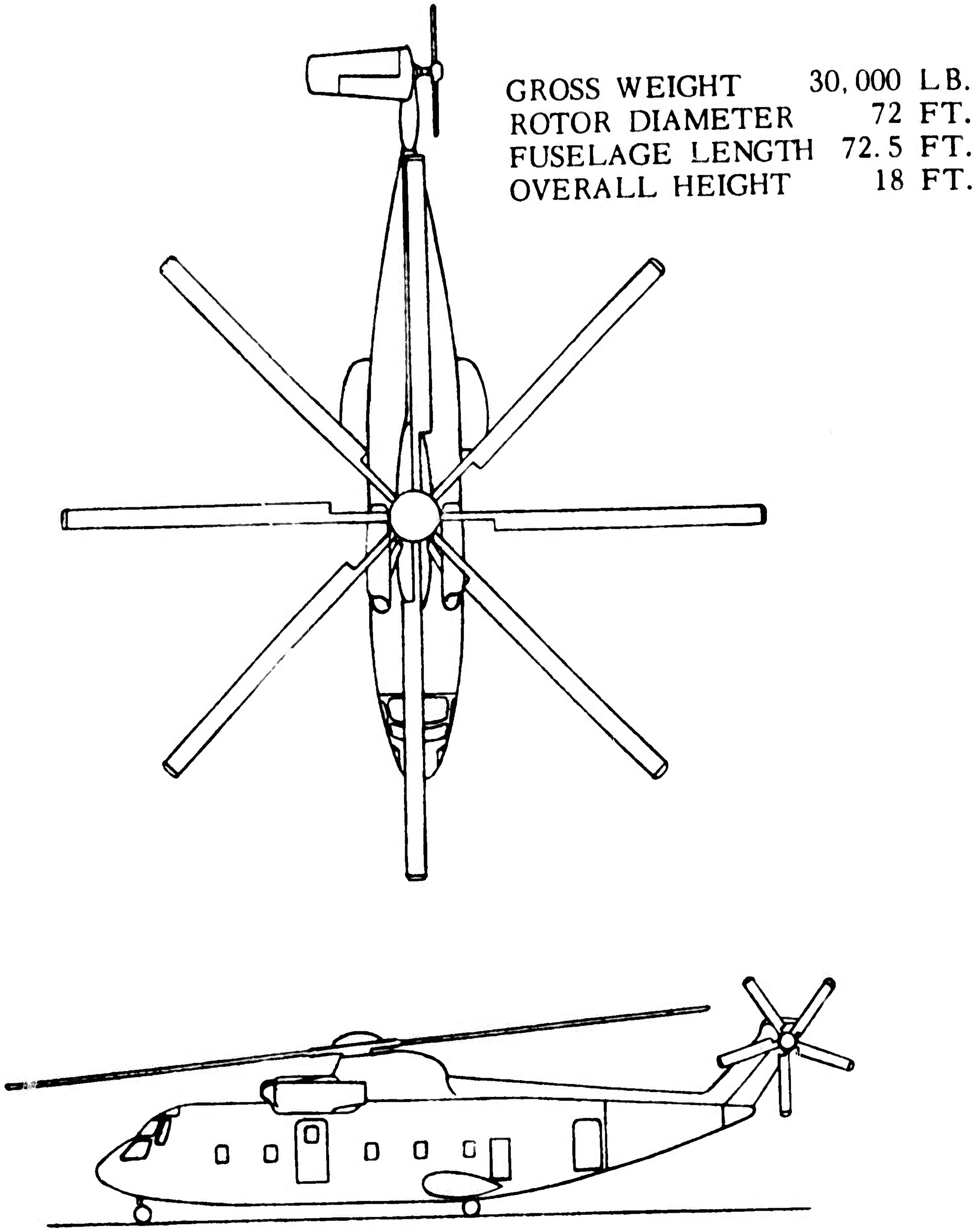
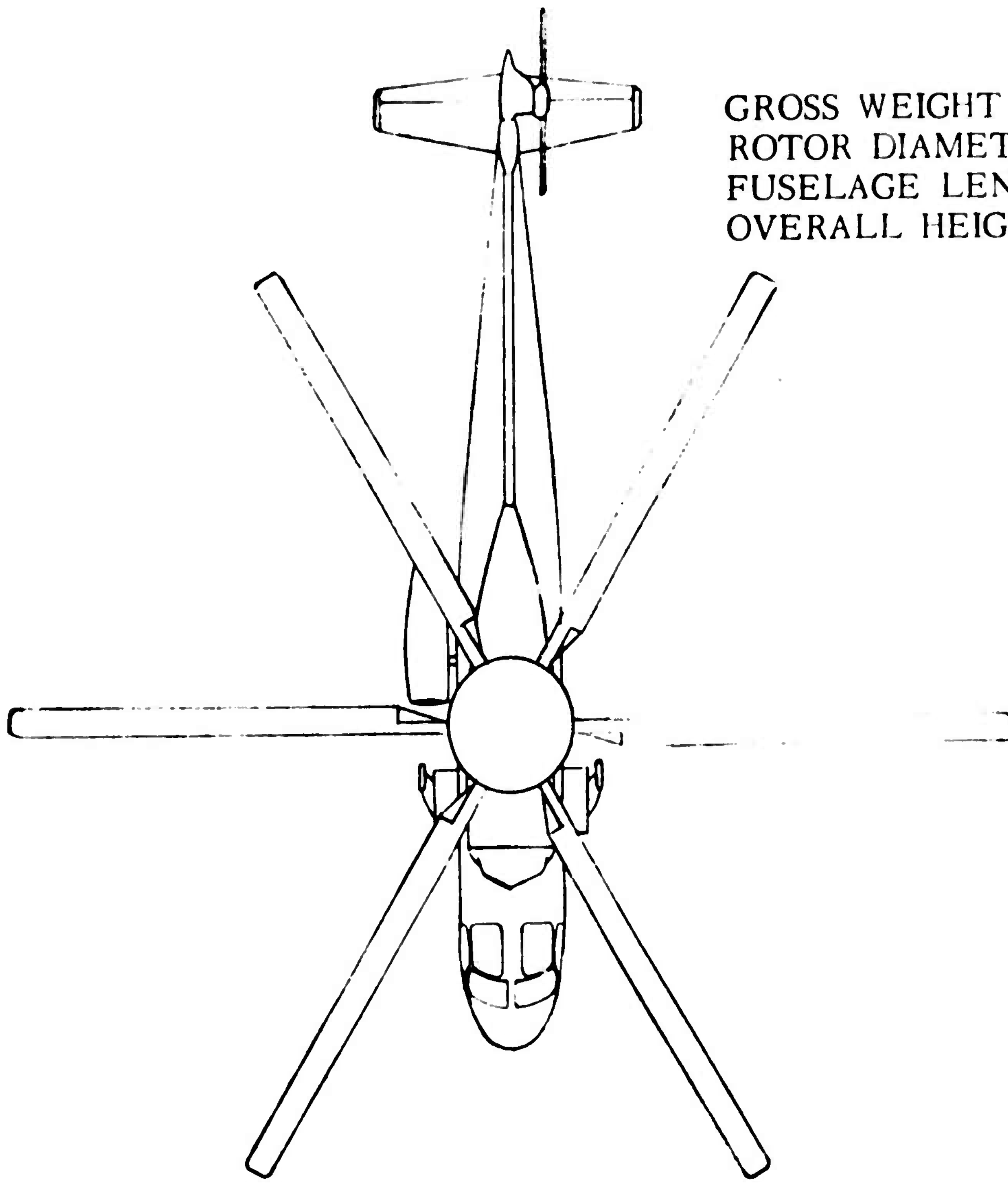


FIG. 2.4 H4 HELICOPTER

GROSS WEIGHT 12,000 LB.
ROTOR DIAMETER 56 FT.
FUSELAGE LENGTH 54 FT.
OVERALL HEIGHT 13 FT.



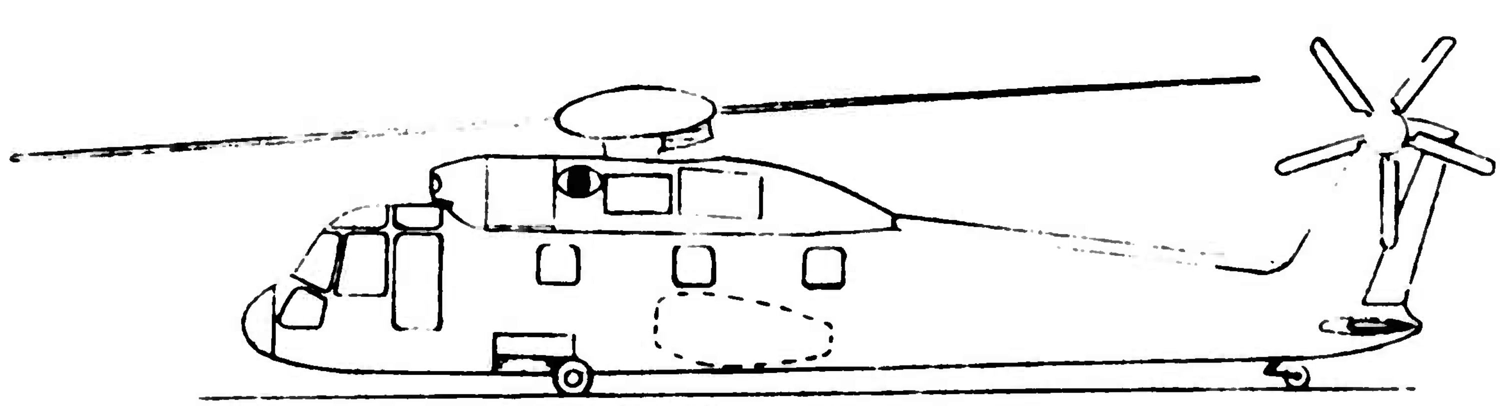


FIG. 2.5 C1 COMPOUND HELICOPTER

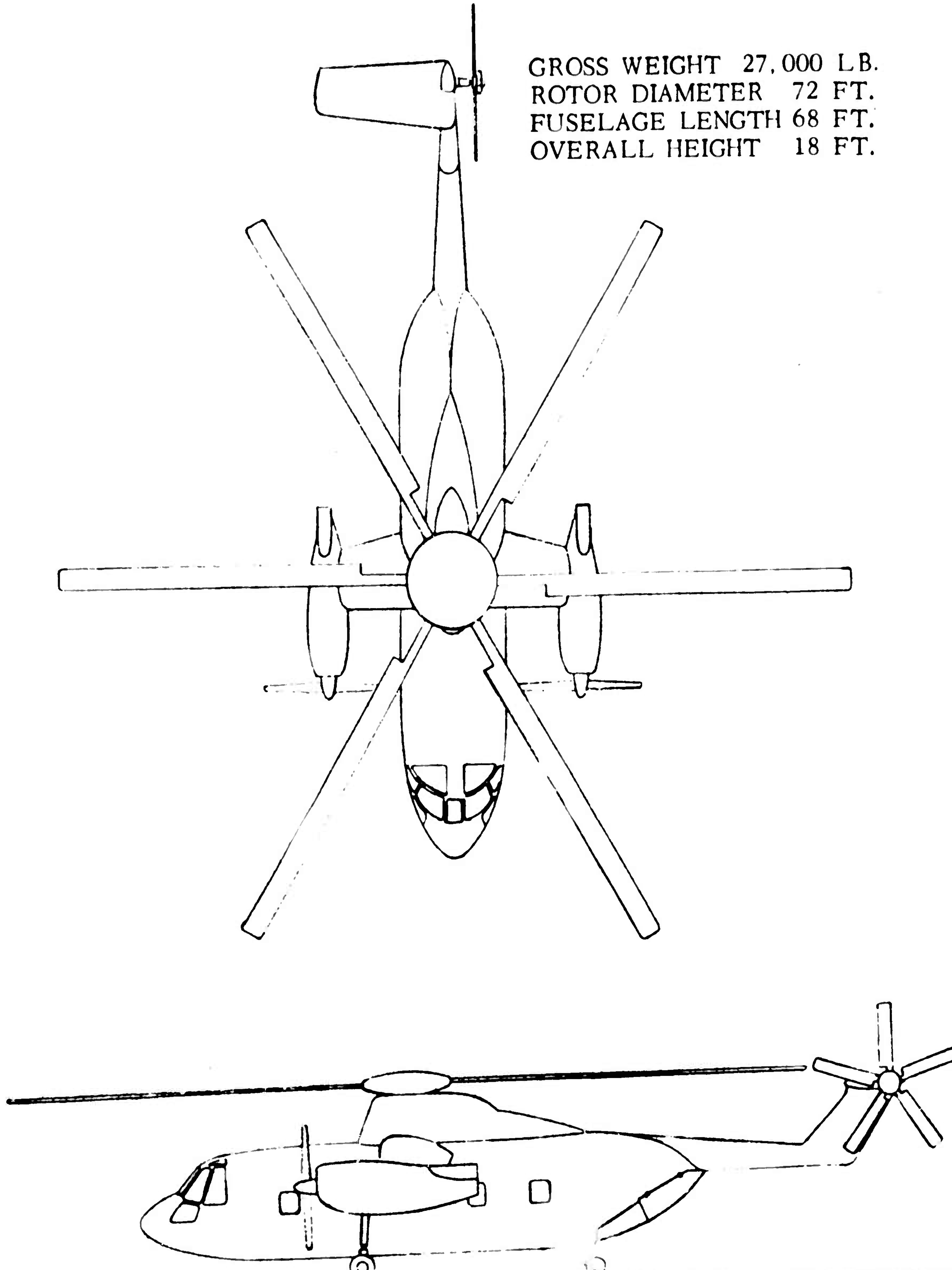
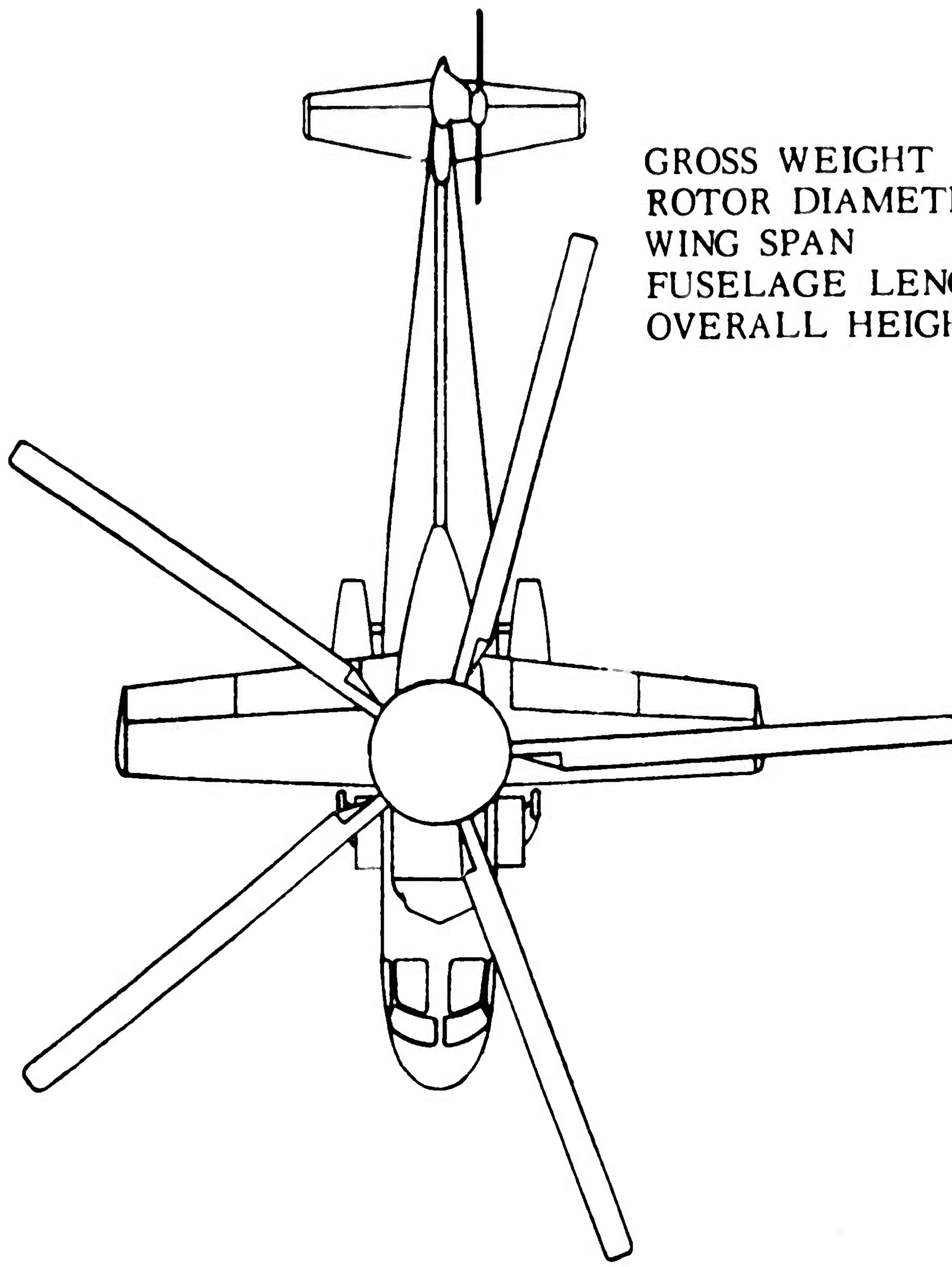


FIG. 2.6 C2 COMPOUND HELICOPTER



GROSS WEIGHT 14,000 LB.
ROTOR DIAMETER 56 FT.
WING SPAN 35 FT.
FUSELAGE LENGTH 54 FT.
OVERALL HEIGHT 13 FT.

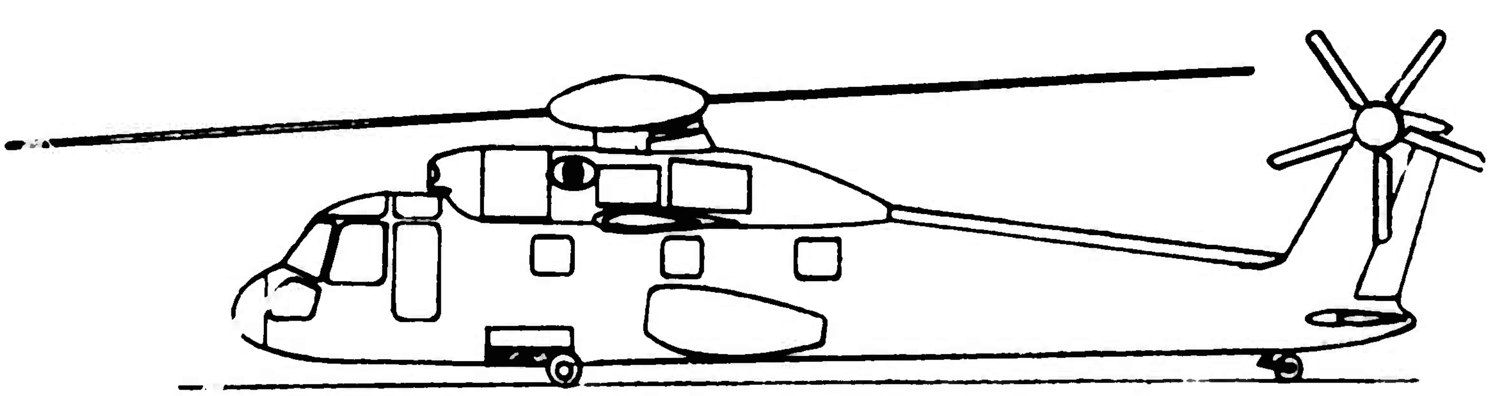


FIG. 2.7 C3 COMPOUND HELICOPTER

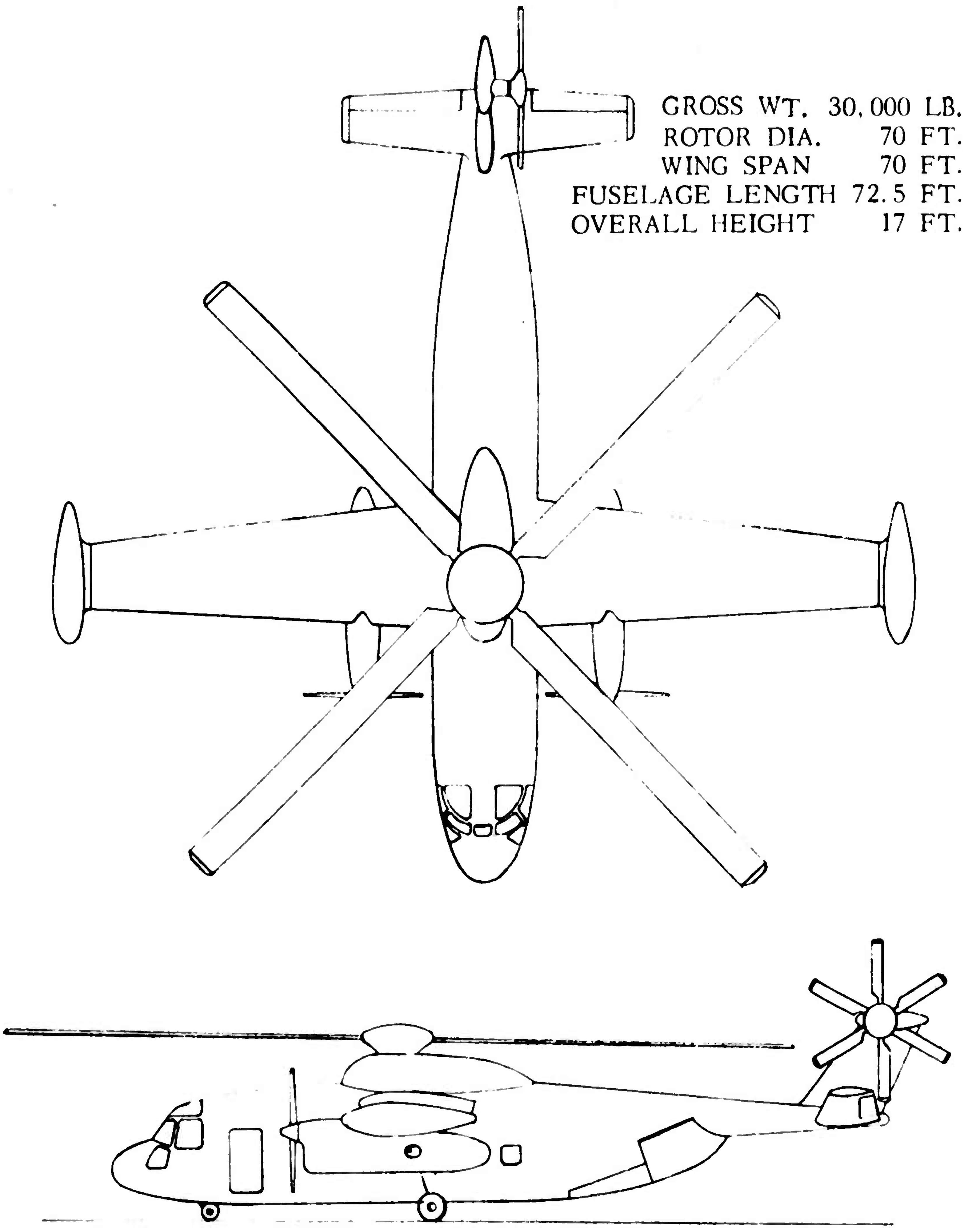


FIG. 2.8 C4 COMPOUND HELICOPTER

BLADE PLANFORMS FOR AEROELASTIC STUDY

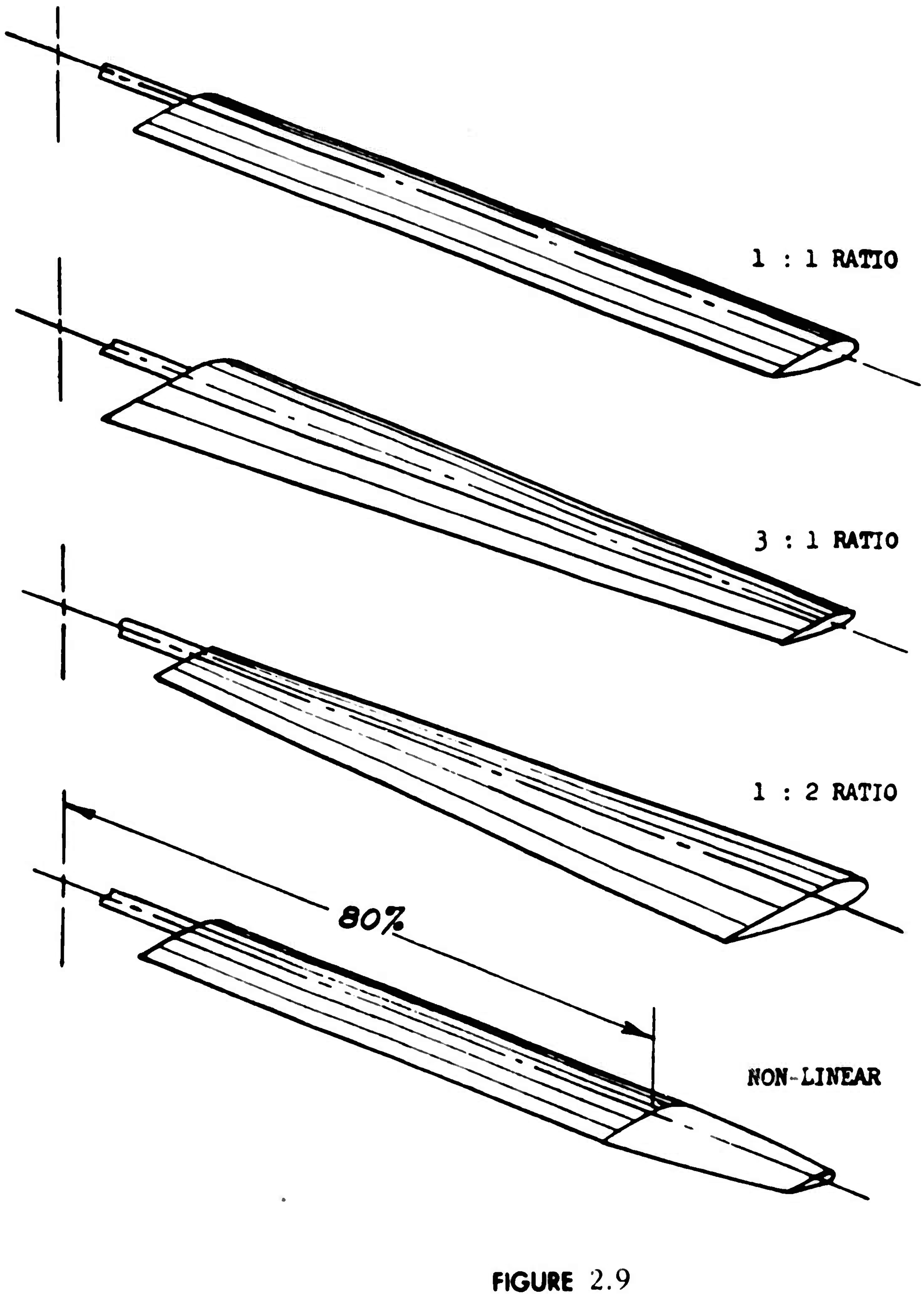


FIGURE 2.9

3. AERODYNAMIC CRITERIA

Basic rotor parameters such as rotor diameter, tip speed, solidity, and number of blades were determined by the Sikorsky Aerodynamics Section using a performance method based upon blade-element strip analysis. Two-dimensional NACA 0012 airfoil data are used in the method, which takes into account both stall and compressibility effects. There are no small-angle assumptions. Also included are effects of flapping on blade-element angle-of-attack.

Figure 3.1 presents a plot of parasite drag versus design gross weight for typical rotary-winged aircraft. It can be seen that the drag follows a (GW) 2/3 variation, corresponding to a wetted area correlation. A line representing a "clean" configuration is assumed for this study, since high-speed operation demands low drag and because Sikorsky experience indicates that drag clean-up through the use of rotor head fairings, retractible landing gear, and perhaps boundary-layer control is becoming more and more a matter of routine design consideration. For the compound helicopter, of course, the additional drag of a wing is added. Selection of rotor parameters to meet high-speed requirements was further based on past Sikorsky experience, as set forth in Reference 3.

The following criteria were applied in the choice of rotor parameters:

1. Required powers are such that normal rated cruise power corresponds to military hover power OGE at 6,000 ft., 95°F.

2. The advancing blade Mach number does not exceed .90 in order to avoid severe compressibility effects.

3. Blade aspect ratio is between 15 and 20 to minimize induced losses and to maintain reasonable blade weight.

4. For helicopters, rotor rpm is held constant for hover and cruise. For compound helicopters, rpm is controlled by Mach number limit (see 2 above).

5. Rotor C_T/σ for hover OGE at 6,000 ft. 95°F will not exceed .10.

6. For compound helicopters, the amount of auxiliary thrust is equal to the sum of fuselage, wing, and rotor drag. This condition means that the control axis is slightly aft of vertical and that the shaft is vertical. The vertical shaft condition is maintained at all airspeeds so that fuselage attitude does not change.

7. For the winged compound helicopters, a wing aspect ratio of 6 was assumed. A wing of this planform and of the size required to produce the necessary cruise lift will cause a total vertical drag in hover of about 10% of the gross weight.

Gross weights in the range of 12,000 and 30,000 pounds are assumed for both the helicopter and the compound helicopter. A helicopter speed of 150 knots and a compound helicopter speed of 250 knots are felt to represent the normal cruise speeds attainable using present technology. High cruise speeds of 200 knots and 300 knots, respectively, are assumed in order to include what is felt to be a limit condition for the two configurations. For each variation in configuration, speed, and gross weight,the rotor system is optimized aerodynamically within the framework of the previously listed assumptions.

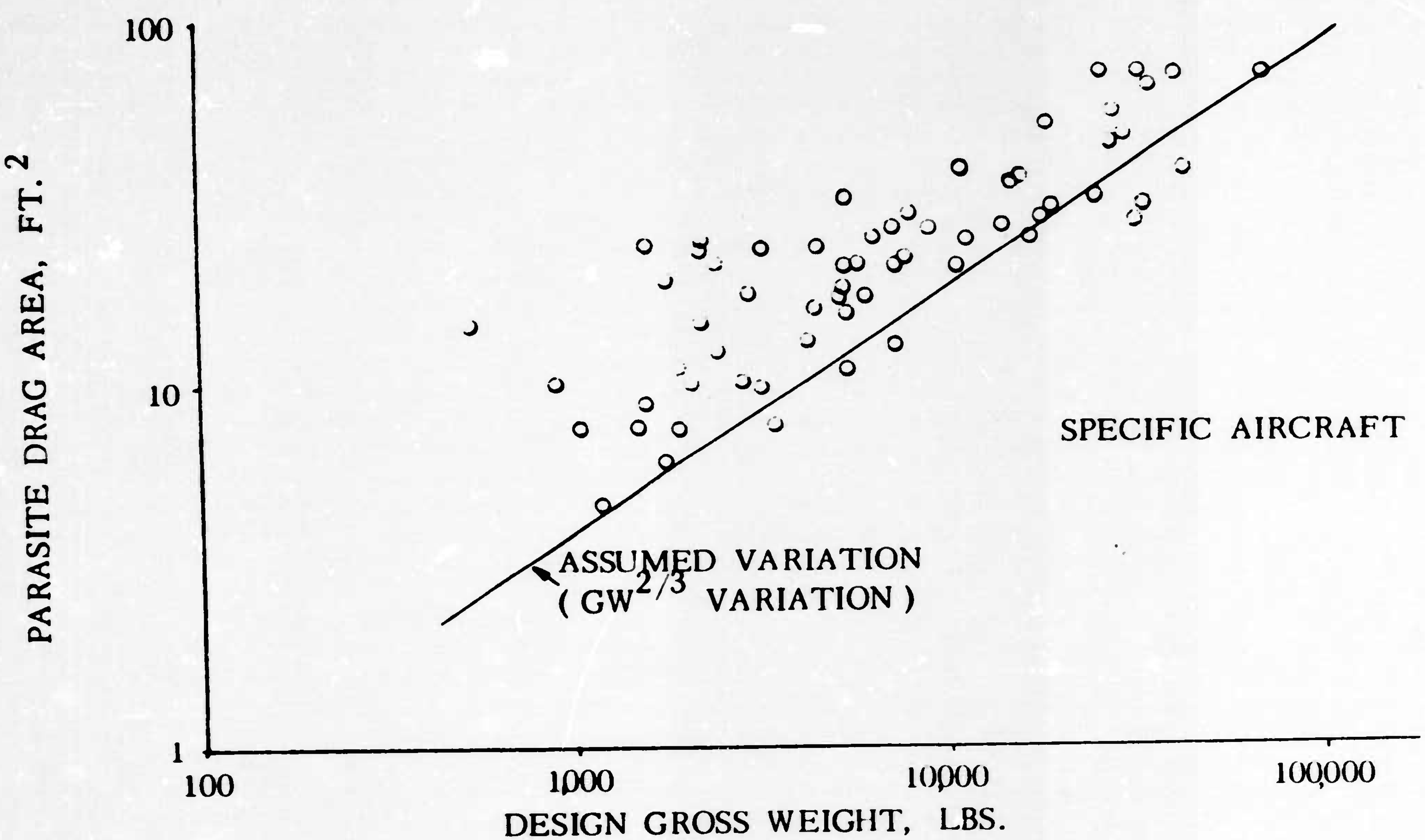


FIG. 3.1 PARASITE DRAG VS. DESIGN GROSS WEIGHT
ROTARY-WING AIRCRAFT

4. BLADE DESIGN CRITERIA

Basic rotor parameters were determined as described in the previous section. These include tip speed, rotor diameter, blade chord, number of blades, and design twist. Based on these parameters, the Blade Design Section then developed structural characteristics for the articulated 1 : 1 planform blades for each of the eight aircraft types to be studied. Blades were designed by standard Sikorsky procedures and met basic load requirements.

Structural design of the 1 : 1 planform blades was based on maximum flight and ground loading conditions. Static, fatigue, and centrifugal effects further defined structural requirements as well as unique mission profiles. Flight condition moments and loads required for structural analysis were defined from a tabular method developed by Horvay (Reference 4). Azimuthal summations were then obtained and applied to the structure to obtain corresponding stress levels. Ground condition criteria were determined from required gravity, wind, and torque considerations.

Extrapolation of uniform blades to those of other planforms (see Figure 2. 9) assumed a conventional Sikorsky-type blade section (see Figure 4. 1). The main load-carrying portion of the blade consists of an aluminum spar, D-shaped in cross section, that forms the leading edge of the airfoil. Trailing edge of the airfoil is formed of aluminum pockets of rib-type construction bonded to the back of the spar. Pockets are separate and are about 12 inches in length.

To extrapolate 1 : 1 planform designs to those of other planforms, a study was first made of section growth trends for a D-spar section. The D-spar section was approximated as shown by Figure 4. 1. From this, analytic expressions could be developed for section properties in terms of nondimensional parameters. Analytic expressions were then evaluated against actual production blade data at the 65% blade radius.

Several trends were noted: (1) The ratio of spar chord to blade chord was found to be essentially constant, and reasonably independent of overall blade aspect ratio and chord (see Figure 4. 2); and (2) The ratio of section depth to chord of the section was also noted to be constant (see Figure 4. 3). This left as the only significant parameter the ratio of average wall thickness to chord of the section.

Plots were then made of I_{xx}, I_{yy}, and cross-sectional area versus section chord for various values of t/C. These are presented in Figures 4.4, 4.5, and 4.6. Circles represent typical D-spar design values at r/R = .65. These plots support the conclusion that section growth takes place along lines of constant wall thickness to spar chord ratio. The fact that actual design points do not lie near the same t/C line for all section properties is primarily attributed to changing numerical accuracy of approximations. But in all cases the growth trend is the same.

This conclusion formed the basis for extrapolation. Characteristics of separate planform blades were now extrapolated from 1 : 1 planform designs by the following criteria:

1. At corresponding blade radial stations, cross-sectional area was held equivalent. By this means, blade weights and centrifugal stresses were kept equal. The only deviation permitted was when extrapolated wall thickness became small. Here, to avoid local spar buckling, a minimum value of 0.15 inch was set.

2. Section properties were extrapolated based on the ratio of spar wall thickness to chord. Knowing chord and section area, this value could be determined and then used to calculate flatwise, chordwise, and torsional stiffness assuming a typical D-spar blade.

For rigid rotor systems, the blade root had to be specifically designed to meet the following criteria based on information provided by the Lockheed-California Company:

1. For planforms of aspect ratio greater than 18, a soft inplane system was used. This required the first inplane bending frequency to be between $0.6\,\Omega$ and $0.7\,\Omega$. The inplane frequency was achieved by reducing root stiffness by removing material and attributing 15% of the frequency decrease to bearing flexibility.

2. For planforms of aspect ratio less than 18, a stiff inplane system was used. Here, blades were tuned so that the first inplane bending mode was near $1.4\,\Omega$.

3. Flatwise flexibility of rigid blades was designed so that the second flatwise bending mode was sufficiently removed from n/rev.

4. Prelag and precone angles for the rigid blade were established from results of the articulated blade analysis at the design

airspeed. Steady coning and lag angles were taken from the articulated analysis, then used to establish root angles for the rigid blade in order to minimize steady root bending moments.

Section properties of blades considered in this study are tabuated in Appendix B, Tables B-1 through B-64.

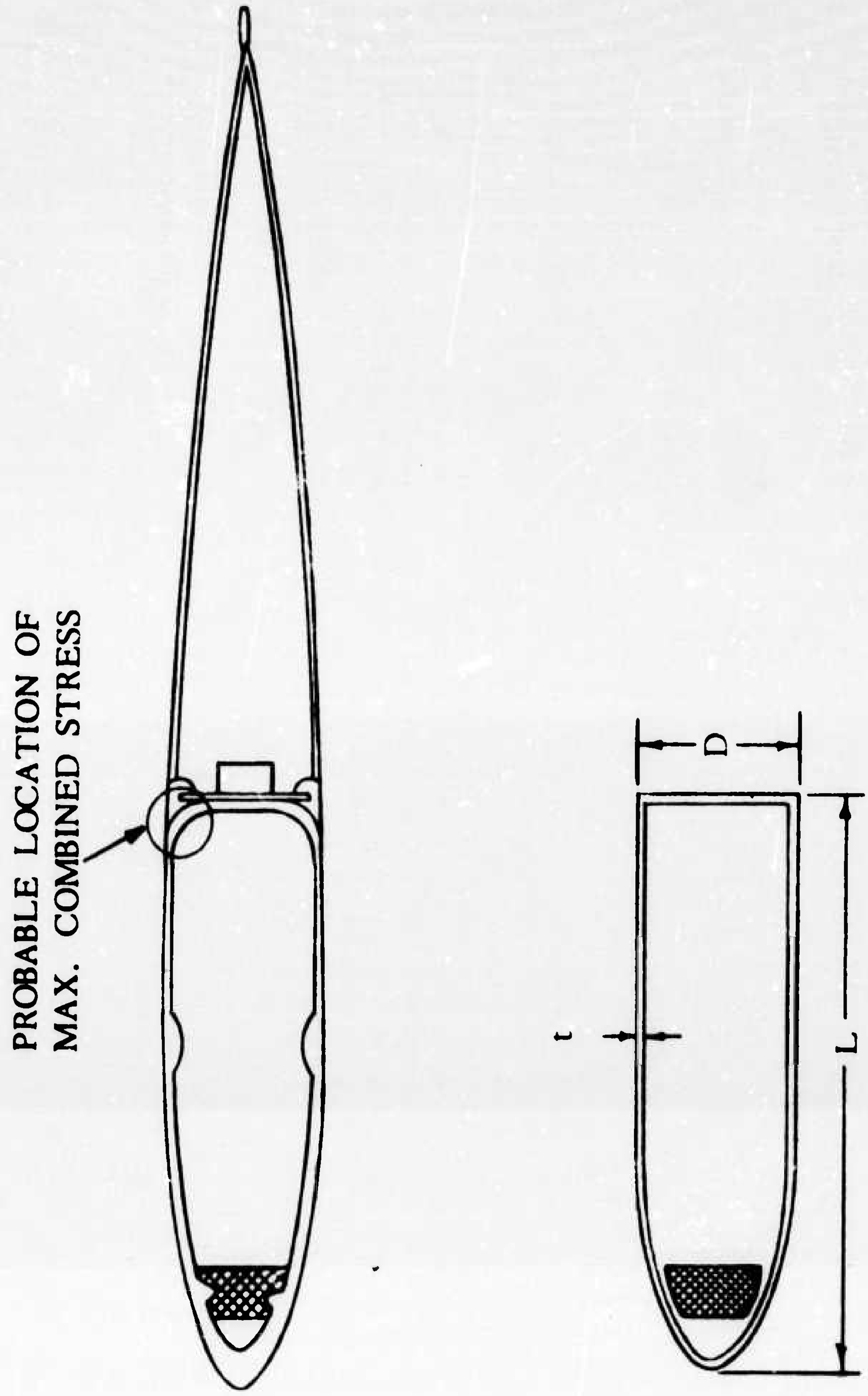


FIG. 4.1 SPAR CROSS-SECTION DETAIL

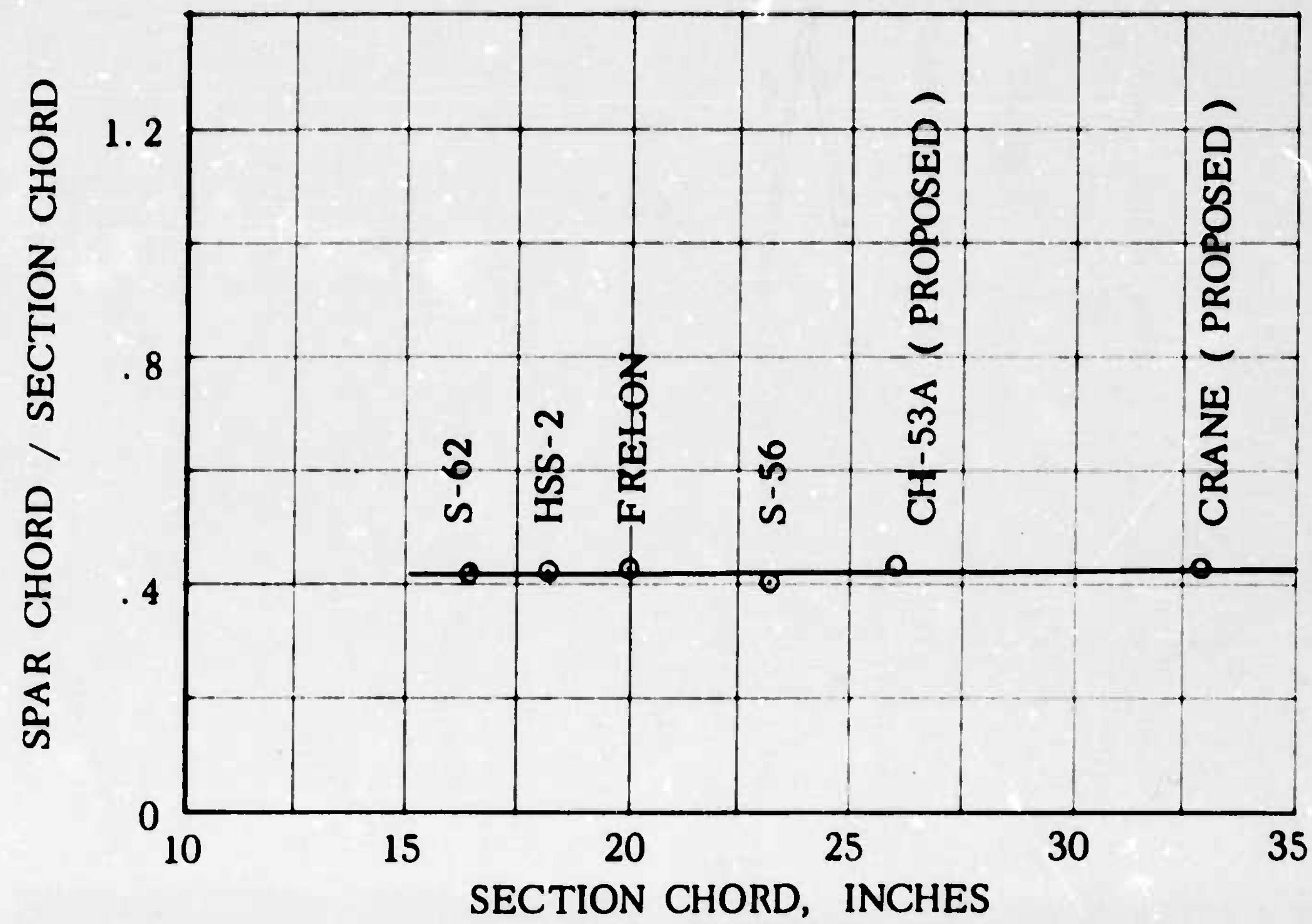


FIG. 4.2 EFFECT OF CHORD ON L/C RATIO

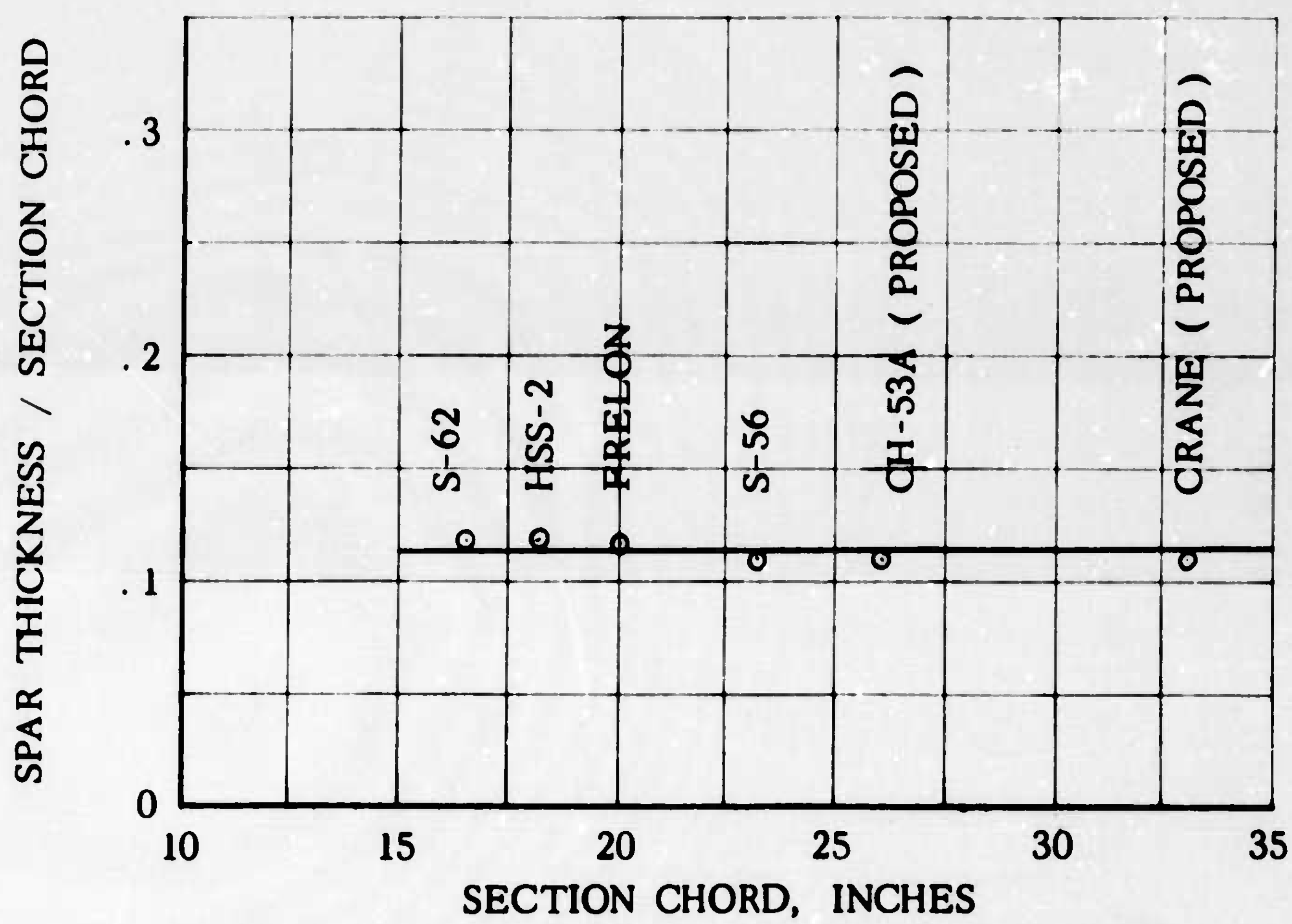


FIG. 4.3 EFFECT OF CHORD ON D/C RATIO

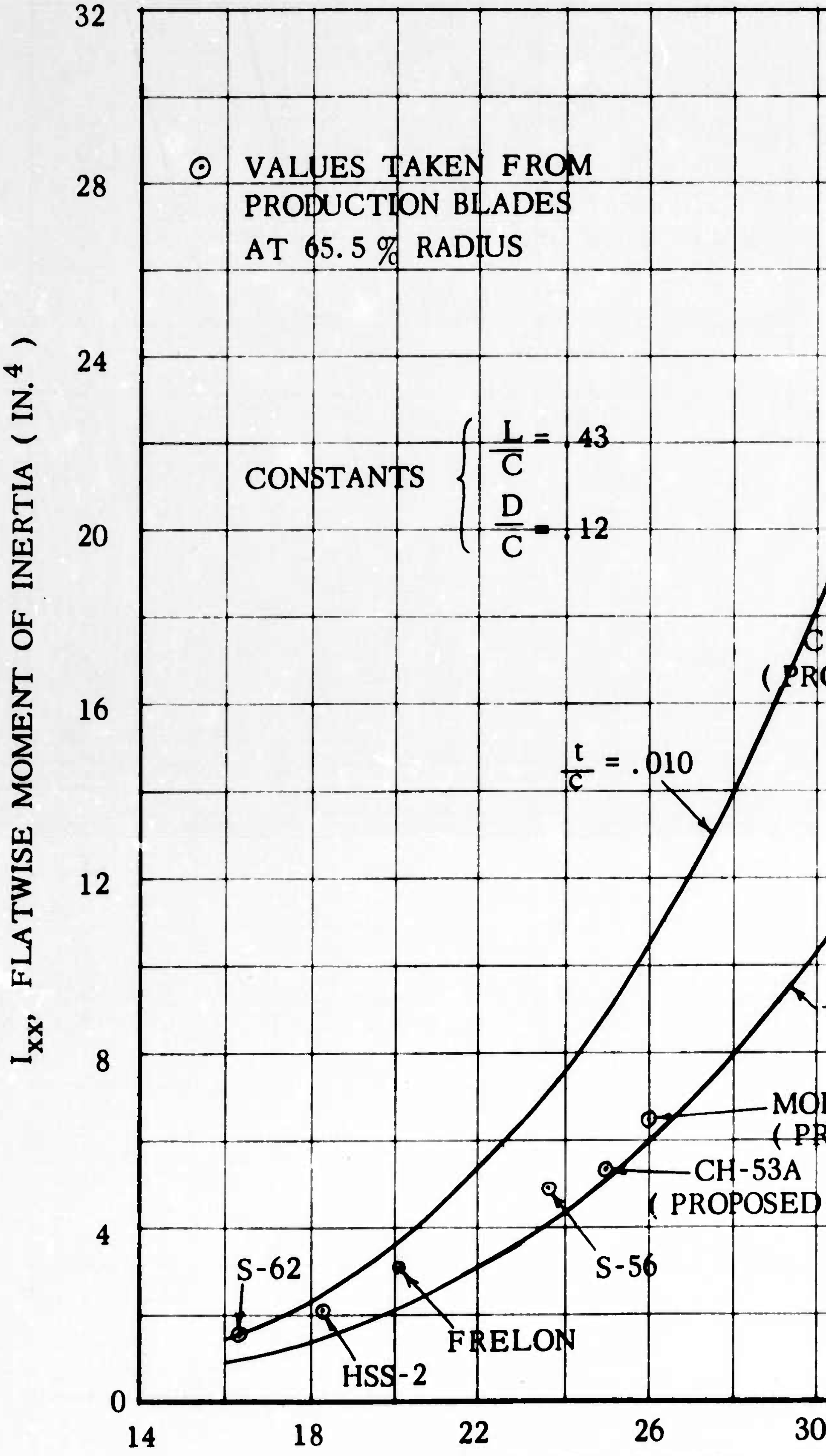


FIG. 4.4 BLADE SECTION I_{xx} DATA

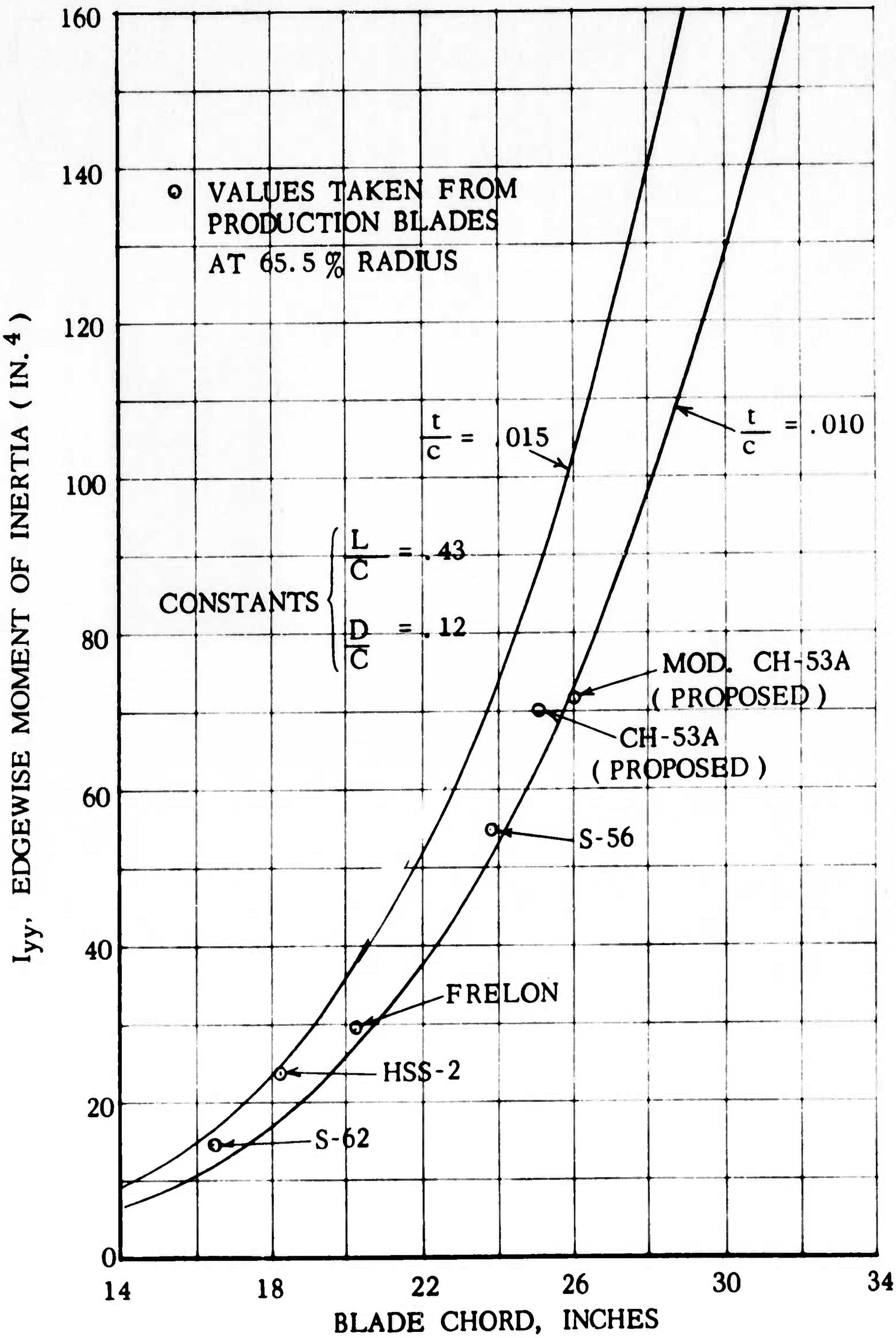


FIG. 4.5 BLADE SECTION I_{yy} DATA

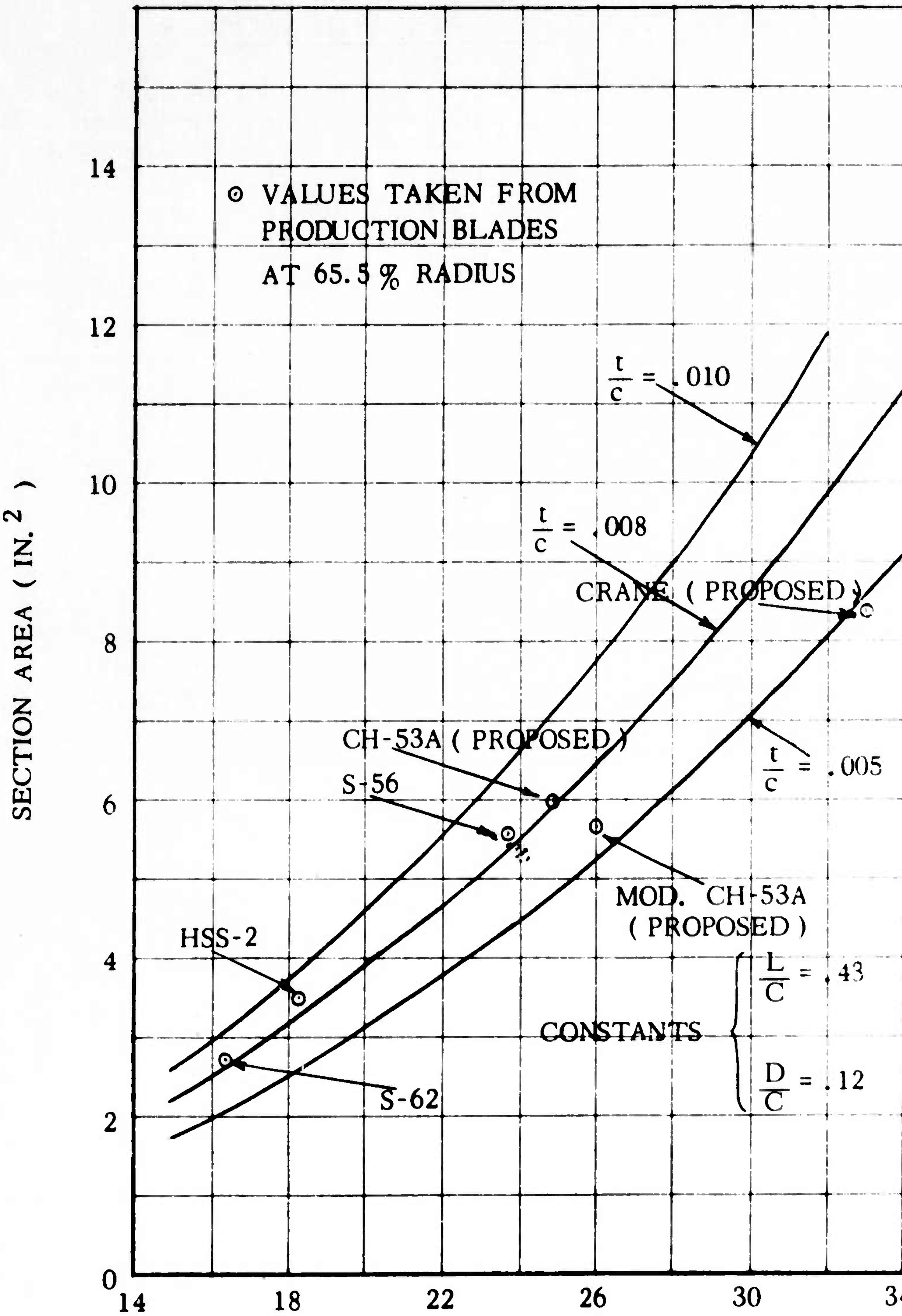


FIG. 4.6 BLADE SECTION AREA DATA

5. DEVELOPMENT OF AEROELASTIC MODEL

To provide an adequate mathematical model for the study, the contractor extended an existing flatwise-chordwise blade dynamic analysis to include torsion. At the same time,the aerodynamic analysis was modified to compute aerodynamic pitching moments. Torsional coupling, while considerably complicating the analysis, introduced effects of torsional coupling on flatwise bending stresses. In addition, blade torsion and control loads could now be determined. Detailed descriptions of both the aerodynamic and earlier coupled flatwise-chordwise blade dynamic analyses are presented in Reference 1. Extension of the method to include torsion is given in Reference 2. Further results of correlation studies and preliminary results of the present aeroelastic investigation are set forth in Reference 5.

A. PROGRAM CHECKING

A systematic procedure was followed to check out computer programs for the aeroelastic study. Prior to calculating flight conditions,it was essential that hand checks and program checks match to eight decimal digits.

Initially, the aerodynamic program was recoded to provide the following refinements:

1. Calculation of aerodynamic pitching moments.

2. Closer tolerance on aircraft trim conditions - gross weight, pitch and roll equilibrium.

3. Provision for retrimming the rotor after the blades have deformed in torsion.

For check-out, a test case was selected. Corresponding sections were checked out by side-by-side comparison with the original aerodynamic program. New portions of the program were checked by hand calculations on a desk calculator.

The new blade forced response program was coded in three steps to include the torsion coupling. Each step was checked independently.

1. The first step was checked readily on a desk computer,for this step involved only blade rigid body motions.

2. The second step determined the steady coupled flatwise-chordwise-torsional response of the blade. This was initially checked by zeroing torsion coupling and comparing results with the earlier program. Following this, the fully coupled response with torsion was checked. Output values for flatwise and chordwise shears, moments, slopes, and deflections, as well as torsional slopes and moments, were compared with hand-computed results by substituting into the basic equations. Hand calculations were done for a number of blade segments until all terms had been picked up. If answers did not check, actual machine procedure was followed by hand to isolate the source of error.

3. The third step determined the fully coupled vibratory response of the blade. Checking required first zeroing out the second step. With this complete, checking procedure was similar to the second step, but more time consuming,for equations were in complex form.

Test runs were made on the computer after checking equations of each step, as described above. Included in these checks,the blade was taken as rigid in torsion in the complete blade analysis. Results were again compared against the earlier flatwise-chordwise program.

B. DESCRIPTION OF AEROELASTIC ANALYSIS

The method of aeroelastic analysis is based upon superposition of separate harmonics of blade-forced response, which result from response of the blade to individual harmonics of airloads. A detailed description of the method has been given in References 1 and 2; a brief description is given below.

1. Calculation of Aerodynamic Loads

For the helicopter to be analyzed, the gross weight, drag, speed, and rotor rpm must be given. Also for the blades, steady-state two-dimensional airfoil characteristics, structural stiffnesses, mass distribution, twist, and root retention must be specified. The rotor disk is considered to be moving at the proper forward tilt to provide enough propulsive force to overcome the net drag of the aircraft. It must also support the aircraft, and there must be sufficient cyclic pitch to keep the rotor in equilibrium. Certain simplifying assumptions are made to initiate the calculation, such as an estimate of the rotor drag and an estimate of the radial position of the resultant thrust vector. These approximations do not affect the final accuracy, for if they are too far in error, this is remedied by a second or third iteration.

For a high-speed condition, constant inflow is taken. The blade is subdivided into up to 24 elements. For each of 36, 10-degree azimuth intervals, the blade is considered set at two blade angles. These angles bracket the expected blade angles. Blade-element aerodynamic lifts are then computed, from which the moment of the thrust about the flapping hinge is calculated as a function of blade angle and azimuth position. The cyclic pitch necessary to maintain the rotor system in equilibrium is then calculated by an iteration to enforce the condition that the first harmonic thrust moment about the flapping hinge is zero.

For calculation of aerodynamic loads, two-dimensional 0012 airfoil data are used. Compressibility effects are taken into account by using separate C_L, C_D, and C_m versus α curves for angles of attack from 0 to 30 degrees for Mach numbers up to 0.95 in 5% increments. To define stall regions above angles-of-attack of 30 degrees, single C_L, C_D, and C_m versus α curves are taken from data in Reference 10.

Final determination of cyclic pitch yields angle-of-attack distribution, rotor drag, power required, location of resultant thrust vector, and thrust moments; and provides pitching moments, resolved thrusts, and drags on 24 blade elements for 10-degree azimuth intervals. A harmonic analysis is performed on this loading, and the steady plus the first seven harmonics of blade element loading (pitching moments, thrusts, and drags) are obtained in complex form.

2. Blade Dynamic Response

Individual harmonics of airloads are next introduced into the coupled blade dynamic analysis. This method is based upon an extension of Myklestad's analysis for rotating beams. There is provision for up to 24 flatwise, edgewise, and torsional degrees-of-freedom with coupling due to twist. Equations are in complex form to allow for aerodynamic damping and phasing of aerodynamic loads. Boundary conditions at the tip of the blade require that shears, moments, and torques are zero. At the root of the blade, boundary conditions are applied consistent with blade root restraint, whether articulated, teetering, or rigid. There is provision for a linear lag damper. Also, with torsion added, provision has been made for control system flexibility and damping.

Analysis for flexible blade dynamics with torsional coupling is done in three steps. In the first step, the blade is treated as infinitely rigid, and rigid body coning, lagging, and twisting are calculated. In the second step, using an iterative relaxation-type method, steady coupled flatwise-edgewise-torsional bending is computed. The iteration is initiated by using the blade slopes and deflections determined in the first step. In the third step, the first through the seventh harmonics of blade coupled responses are determined. Steady response values from the second step are used so that torsional coupling of vibratory forces times steady deflections and steady forces times vibratory deflections can be included.

Total forced response of the blade is next determined by superposition of separate harmonics of blade dynamic response. This yields the azimuthwise distribution of moments, torques, deflections, twist, and stresses at each of 24 blade stations for 10-degree azimuth intervals.

C. EFFECTS OF TORSION

The introduction of torsion, while considerably complicating the new aeroelastic analysis, gave new information on the effects of torsional coupling on blade flatwise bending stresses. In addition, it permitted calculating blade torsion and associated control loads.

Effects of torsion on rotor blade flatwise bending moments are presented in Figure 5. 1. Here, results of a fully coupled blade dynamic response calculation are compared with those of the method of Reference 1, which treats coupled flatwise-edgewise response but does not include torsion. In the case of the results shown with torsion, the rotor has been retrimmed for torsional deformation, and the calculation repeated. An increase in calculated flatwise bending moments is observed with introduction of the torsional degree-of-freedom. Figure 5. 2 compares calculated results, with and without torsion, against flight test data for the S-58 (H-34) helicopter. Results suggest closer correlation with flight test data by taking torsion into account.

Given in Figure 5. 3 is a comparison between measured and calculated control loads for the S-58 at 110 knots. Measured data were taken from Reference 7. Computed control loads are seen to be somewhat higher than measured values, but the same general character of curve is observed in both measured and calculated results. The peak in the measured data at an azimuth position of 70 degrees was considered questionable, since this was defined by one data point and was not evident in measured inboard blade torsion ($r / R = .15$) for the same flight condition.

Effect of forward speed on calculated helicopter control loads is illustrated by Figure 5. 4. Given are results for the S-61 helicopter at airspeeds of 100, 120, and 140 knots. As can be seen, the plots indicate a significant build-up in pushrod loads as airspeed is increased. Also noted and indicated by the plots is an increase in higher harmonic content with advance in airspeed.

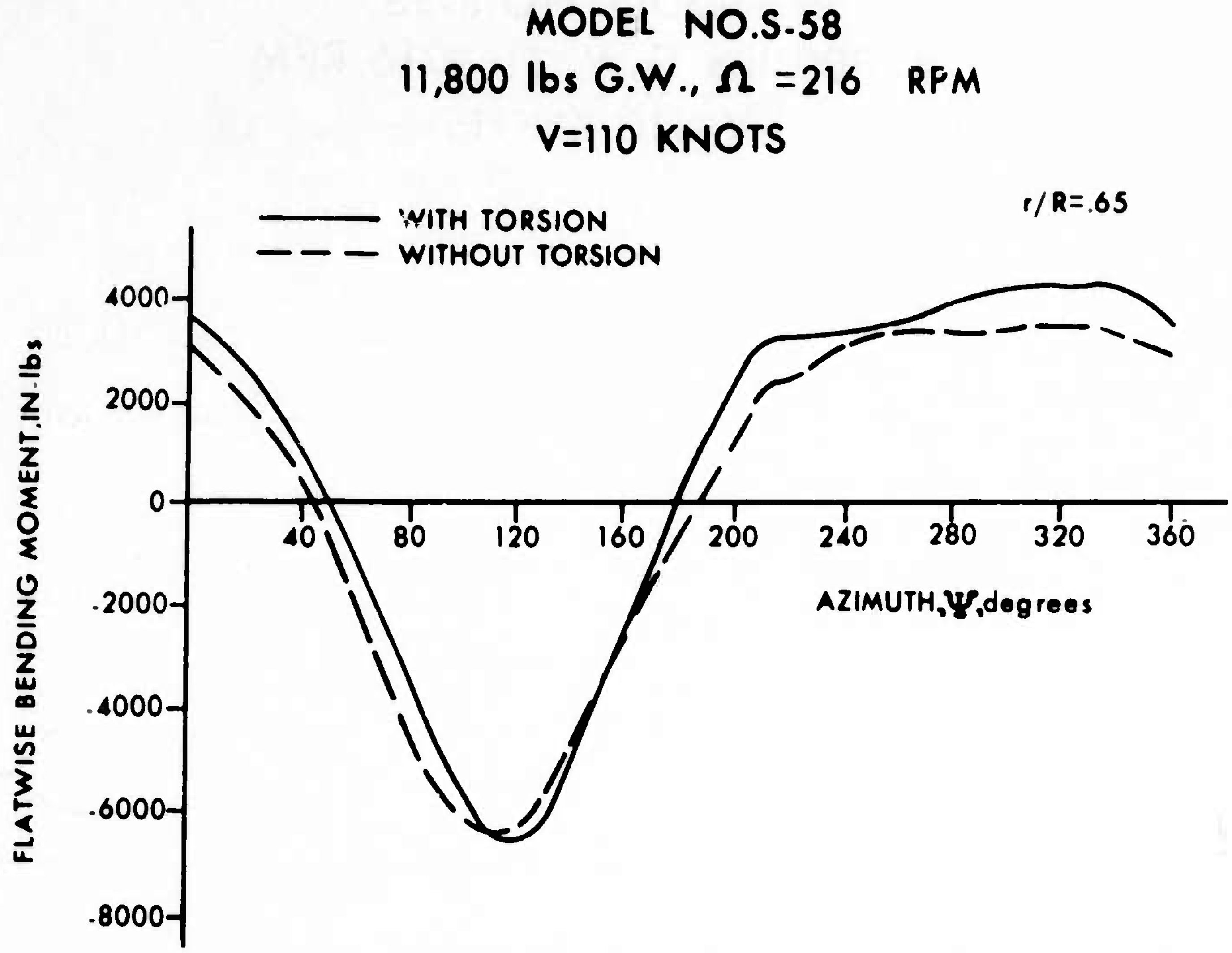


FIGURE 5.1 EFFECT OF TORSION ON FLATWISE MOMENT

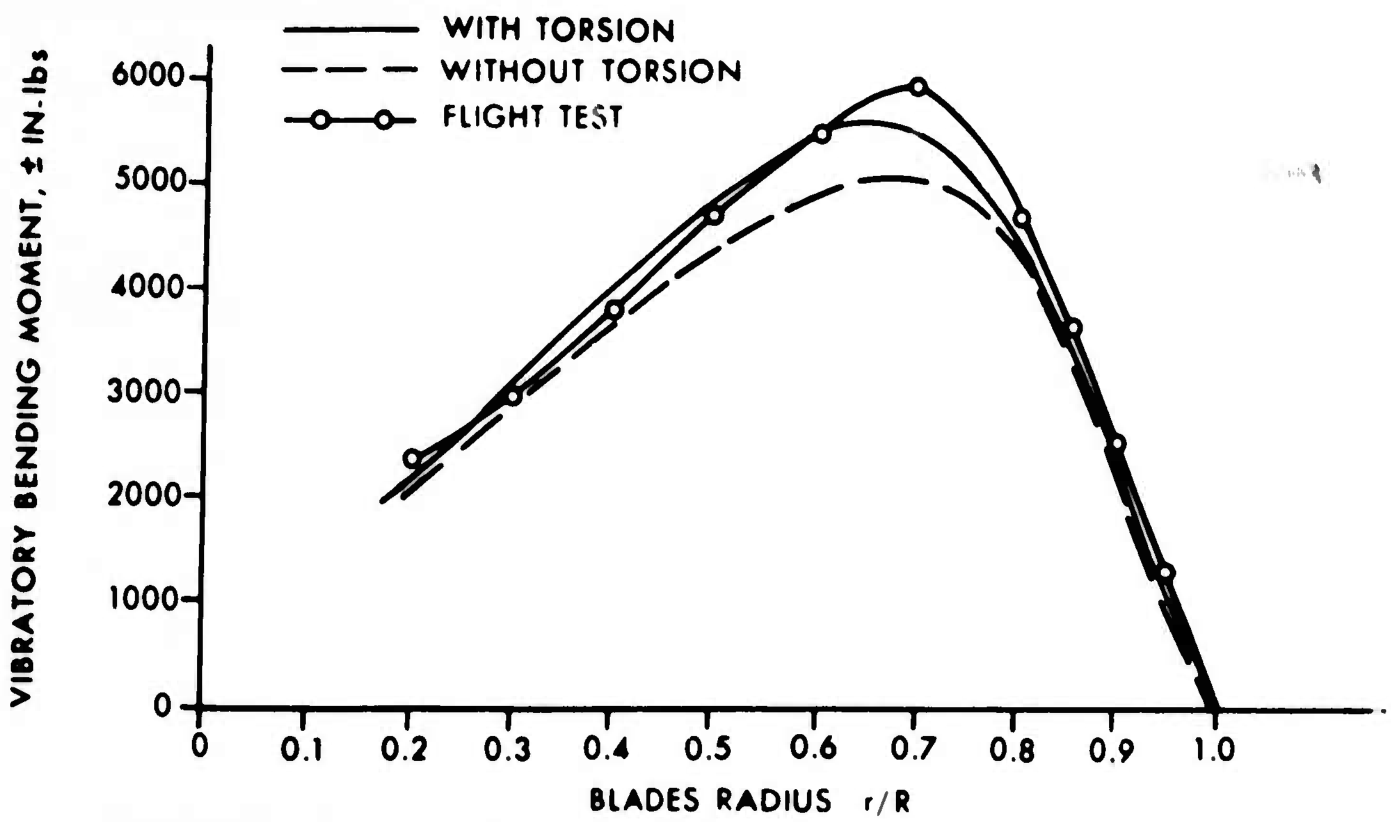


FIGURE 5.2 CALCULATED MOMENTS COMPARED WITH FLIGHT TEST

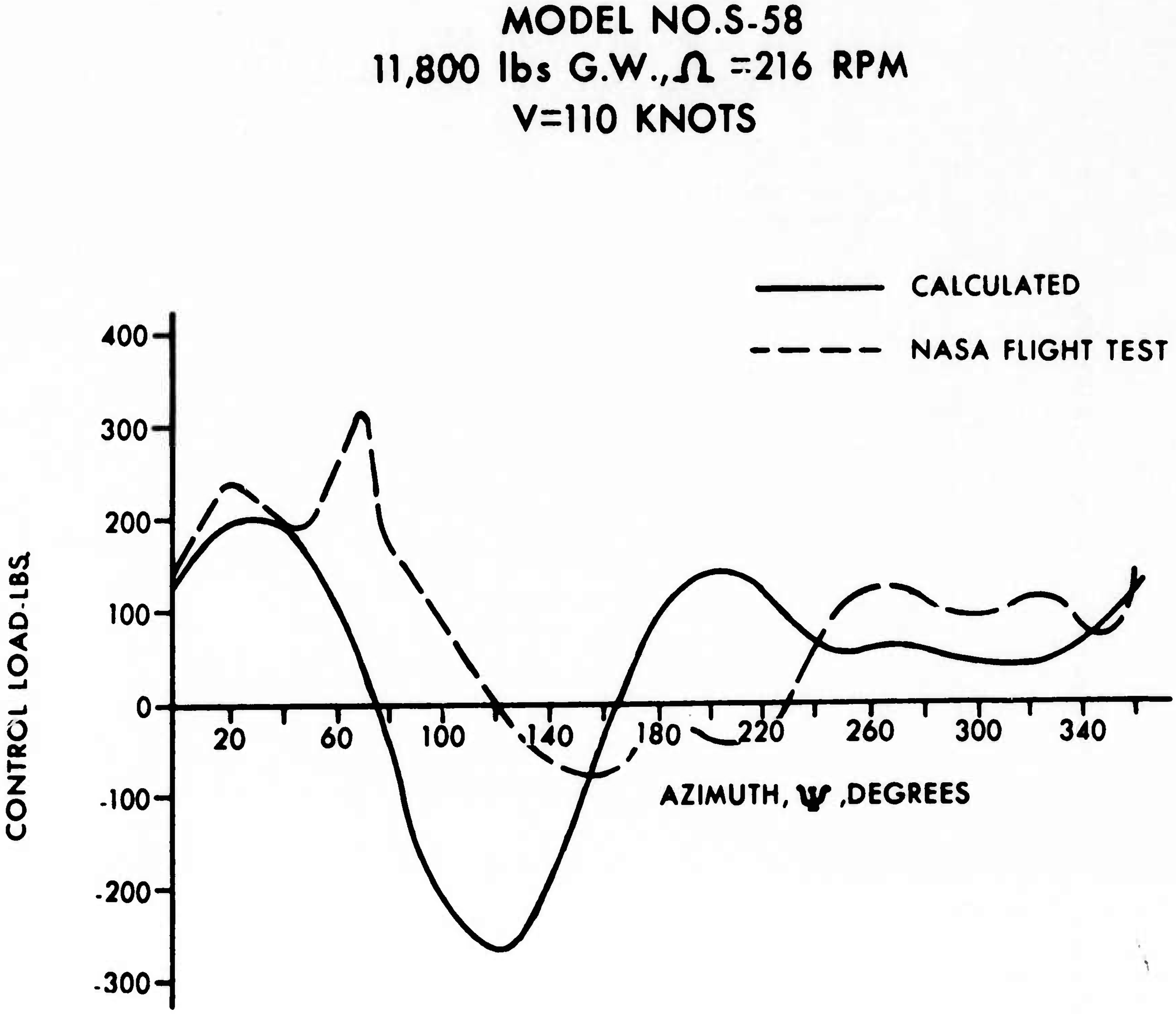


FIGURE 5.3 CALCULATED CONTROL LOADS COMPARED WITH FLIGHT TEST

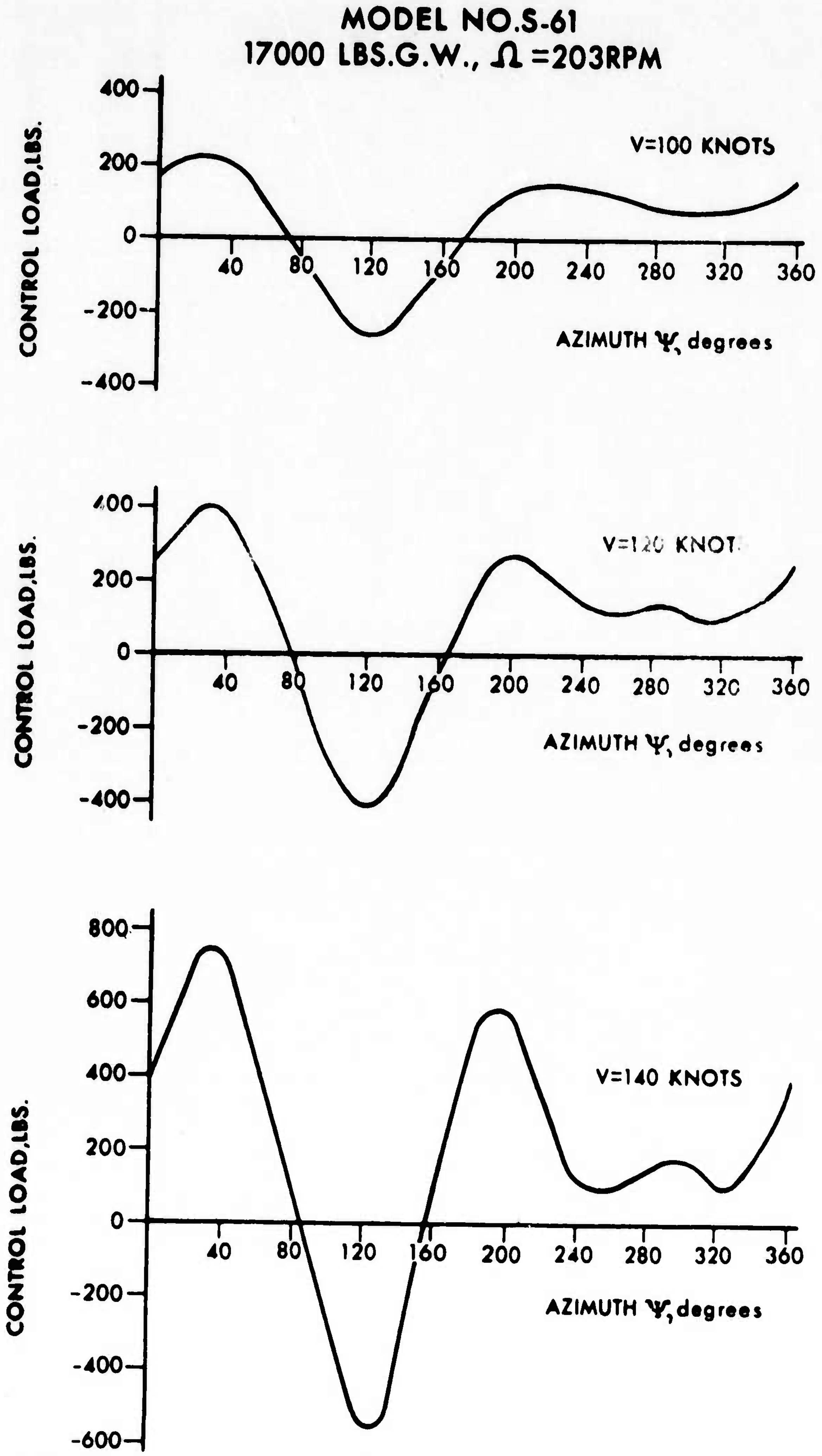


FIGURE 5.4 EFFECT OF FORWARD SPEED ON CONTROL LOAD

6. CORRELATION WITH FLIGHT TEST DATA

Using constant inflow, the method of analysis described shows good agreement with measurements in predicting performance. This is illustrated by Figure 6. 1. Here, calculated and measured power are shown to compare favorably for the S-61 at two gross-weight conditions. The computed values include power required for the tail rotor and accessory drives. Coefficients of drag for the blades were incremented by a $\Delta C_D = .002$ to account for additional roughness of the actual blade compared to a polished wind-tunnel specimen. Note that good agreement is achieved even at low airspeeds where effects of variable inflow have been shown to be large. Comparisons also indicate that the method described provides performance results consistent with standard performance calculations in use.

Figures 6. 2 and 6. 3 compare calculated blade vibratory bending moments and stresses with flight test values for an articulated rotor helicopter. Given in Figure 6. 2 is a comparison of the radial distribution of one-half peak-to-peak bending moments against flight test data for the S-58 (H-34) helicopter. Data are shown for 110 knots. The test helicopter was instrumented by Sikorsky Aircraft under U. S. Army TRECOM contract. Flight tests were conducted by NASA at Langley Field, and preliminary results of tests were released in Reference 7.

Effect of forward speed on vibratory blade stresses and results of correlation are shown in Figure 6. 3. Here, flight test data taken at Sikorsky Aircraft are compared with calculated values for the S-58 at speeds above 100 knots. Each test point shown on the plot represents an averaging of data taken in three separate flights.

Correlation studies for a rigid-rotor helicopter were based on data furnished by the Lockheed-California Company for the CL-475 helicopter. Data included detailed information on blade stiffness and mass distribution. Also provided was a blade resonance diagram, a curve showing blade status deflection, and flight-measured vibratory bending moments along the blade at a number of airspeeds.

Results of earlier studies (References 1 and 2) have shown good correlation in predicting one-half peak-to-peak stresses at higher airspeeds using constant induced velocity. Thus, for correlation purposes, the highest airspeed was selected for which complete CL-475 data had been furnished. This was 100 mph. The blade was subdivided into 20 segments in the fully coupled flatwise-chordwise-torsional analysis, allowing 60 degrees of freedom. The first step in the analysis was to run the calculation as a nonrotating beam to check analytical stiffness and weight characteristics against Lockheed's data for static deflection. Good agreement was achieved as shown by Figure 6. 4.

The second step in the rigid-rotor correlation program was to determine flexibility of spindle bearings at the blade root. This was achieved by varying the flatwise and chordwise root springs in the analysis until there was good agreement with Lockheed's blade resonance diagram as shown in Figure 6. 5. From this, effective springs of 1. 75 million inch-pounds per radian and 4. 00 million inch-pounds per radian were determined for respective flatwise and edgewise root stiffness. Differences between calculated and measured third flatwise modes shown by Figure 6. 5 were attributed to motion of the rotor head. Test results had been obtained by shaking the hub with nonrotating blades where motion of the hub would tend to increase the natural frequency.

The third step in the correlation was to run the complete aeroelastic analysis at 100 mph using constant inflow. Here, the rotor was trimmed, cyclic pitch was determined, and aerodynamic loads were calculated. Harmonics of aerodynamic loads were then applied, and individual harmonics of blade response were superimposed. The radial distribution of calculated blade vibratory bending moments is shown to compare favorably with Lockheed's flight measured values in Figure 6. 6.

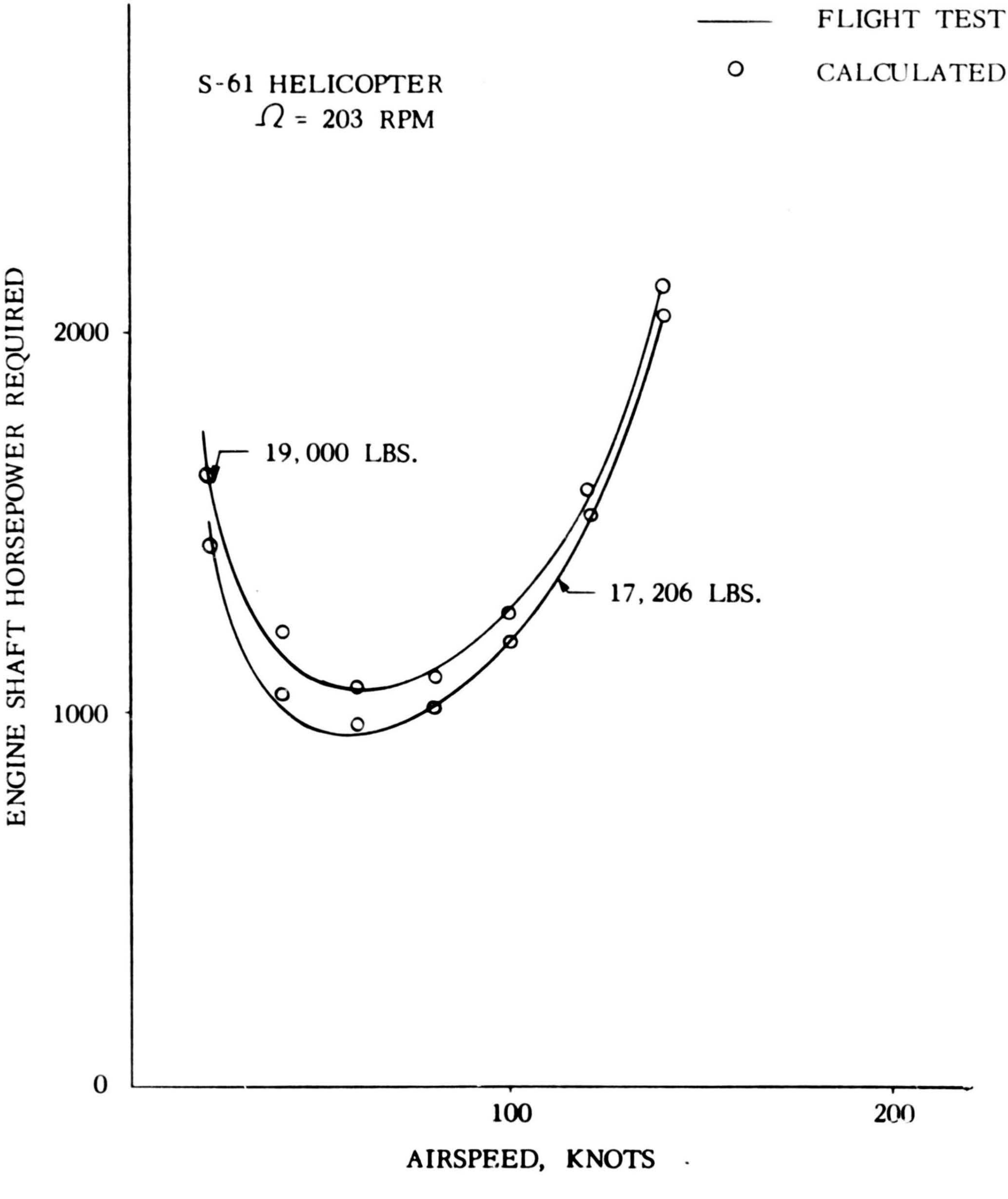


FIG. 6.1 EFFECT OF VELOCITY ON HORSEPOWER

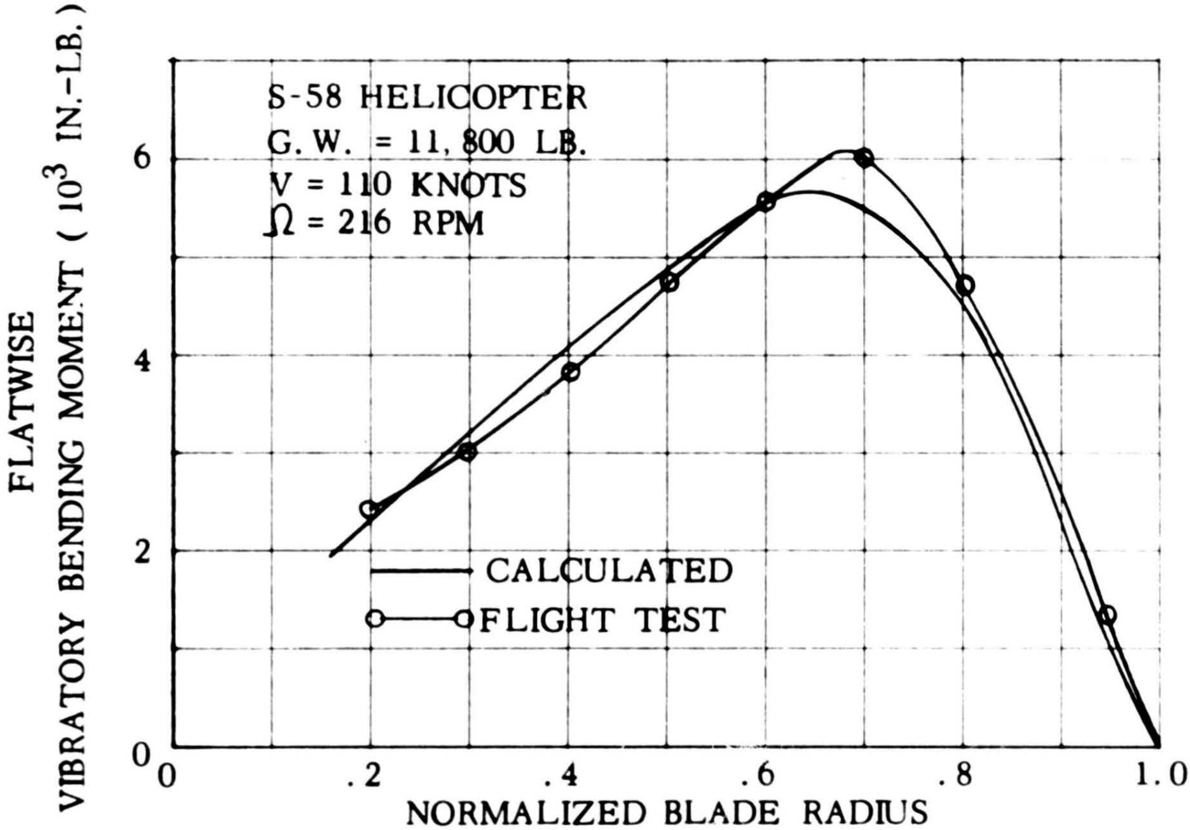


FIG. 6.2 VIBRATORY BENDING MOMENT ENVELOPE

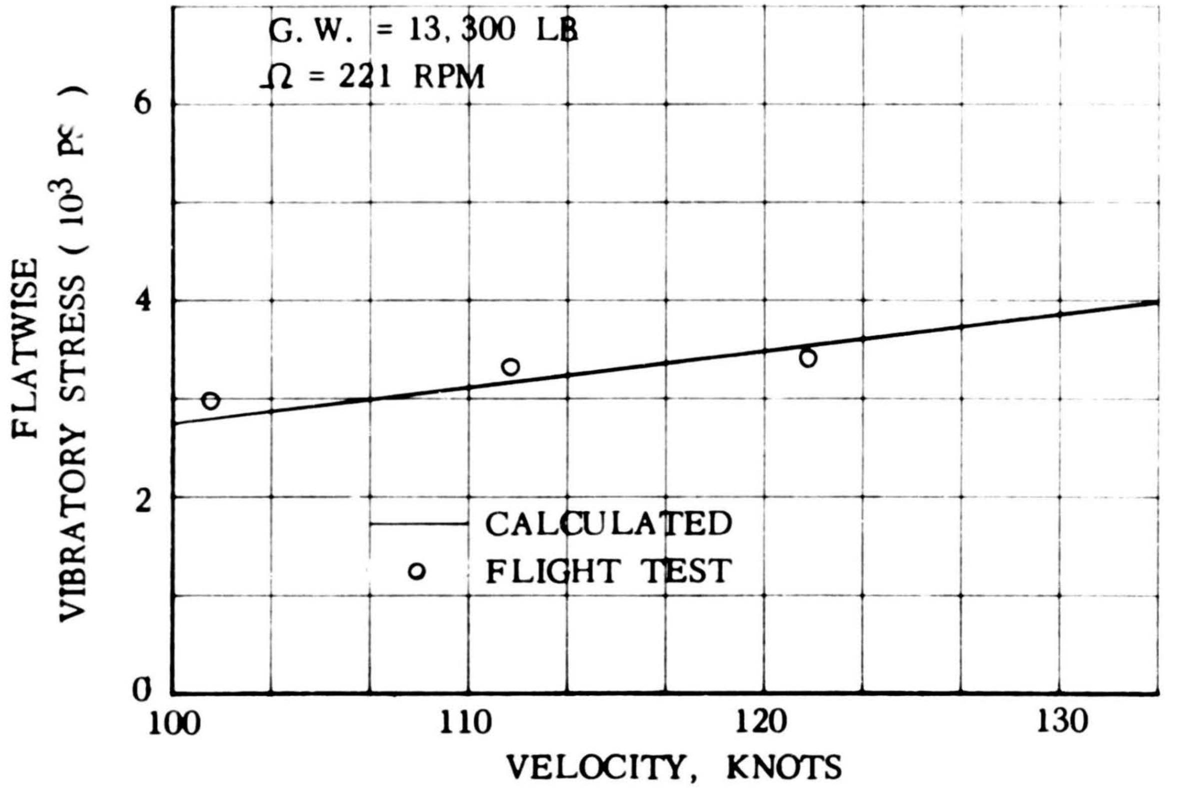


FIG. 6.3 EFFECT OF VELOCITY ON VIBRATORY BENDING STRESS

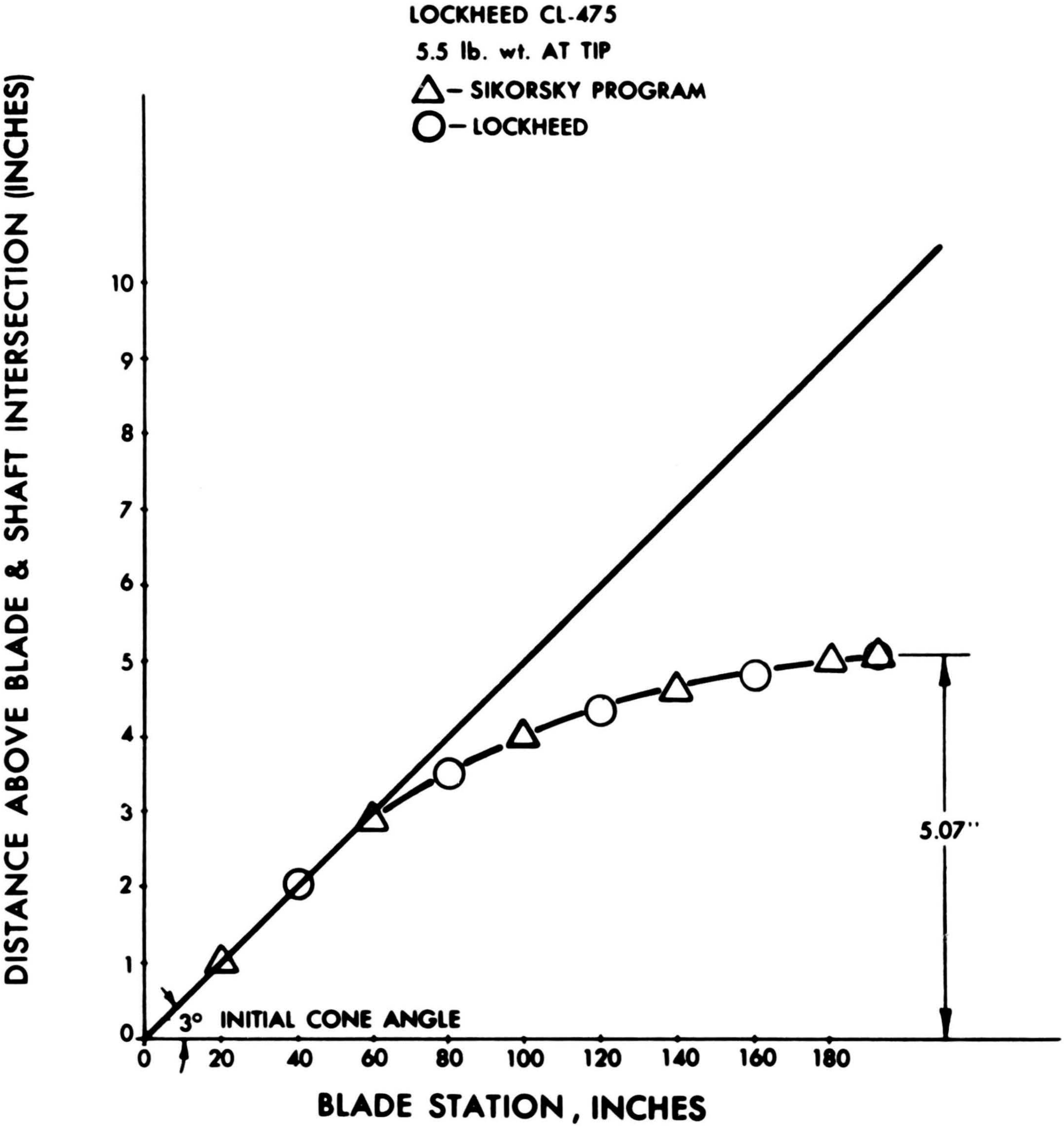


FIGURE 6.4 BLADE STATIC DEFLECTION CURVE

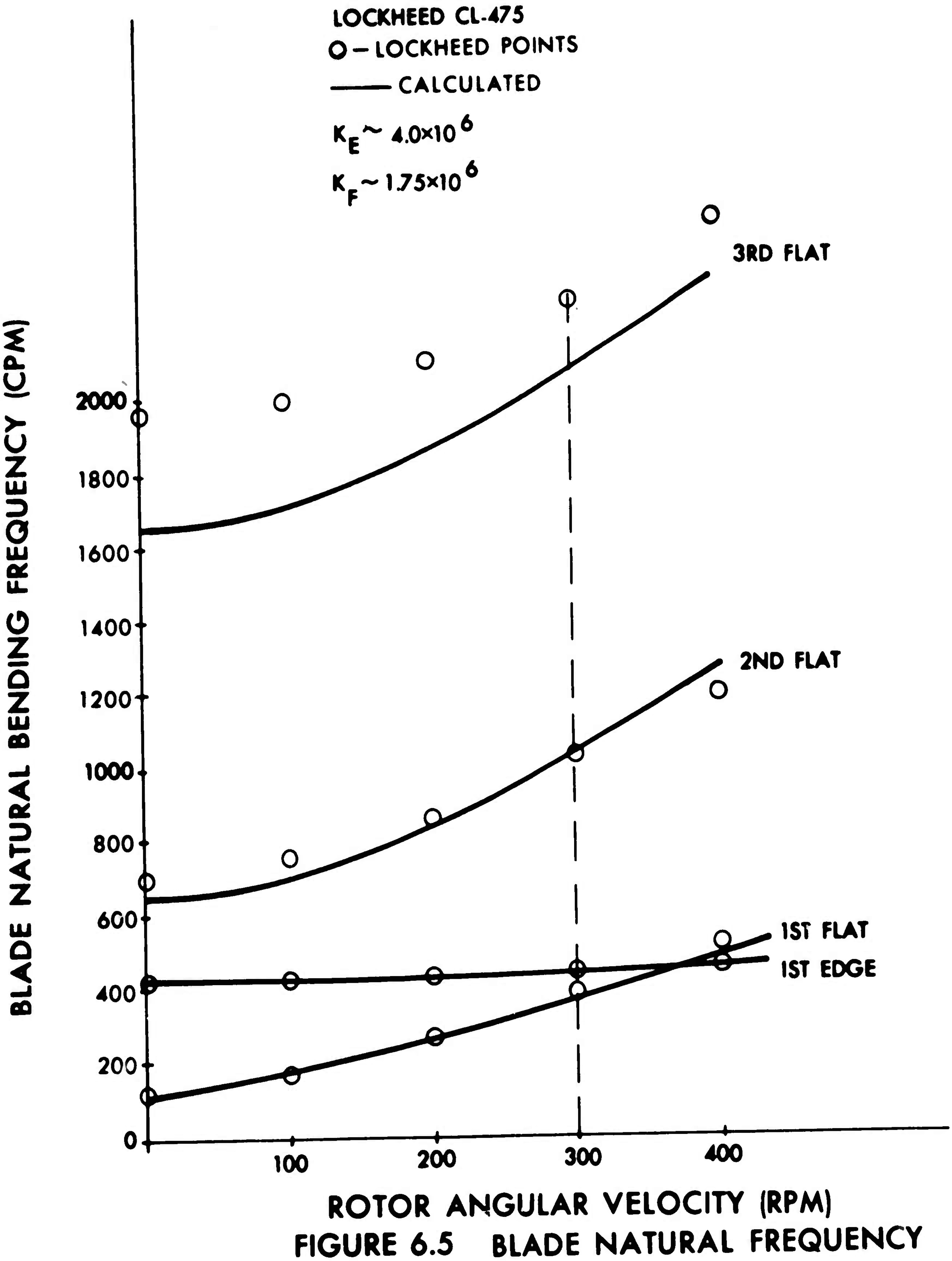


FIGURE 6.5 BLADE NATURAL FREQUENCY vs ROTOR ANGULAR VELOCITY

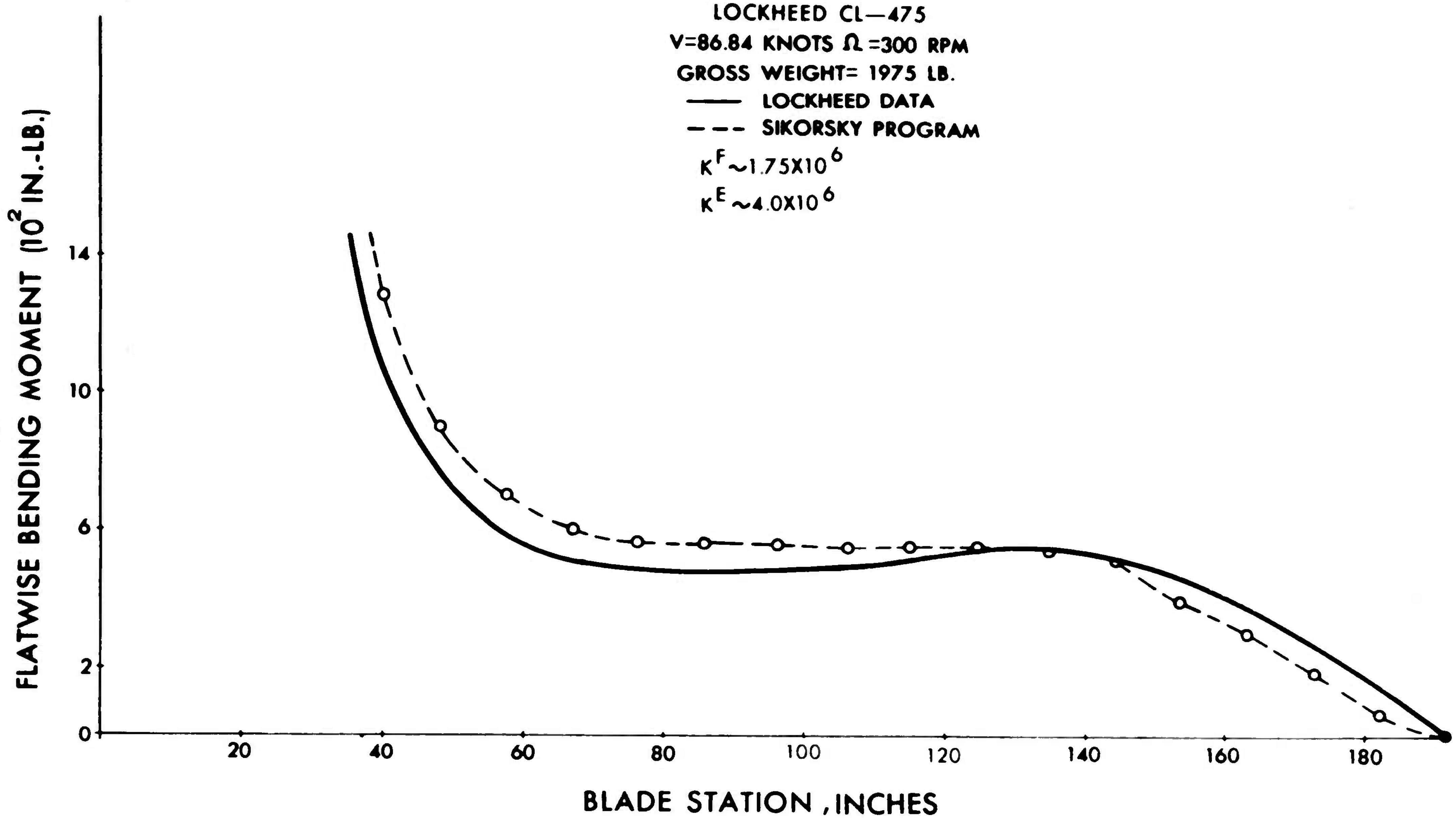


FIGURE 6.6 FLATWISE BENDING MOMENT vs BLADE STATION

7. TWIST AND PLANFORM VARIATIONS

Presented in Figure 2. 9 are the four blade planforms considered in the investigation. Tables 2. 2, 2. 7, and 2. 8 give the planform versus twist schedule followed. As shown by Figure 7. 1, only linear rates of blade twist were considered. Here, nominal twist refers to rate of twist based on total rotor radius and does not refer to actual twist in the spar of an offset blade, which is somewhat less.

Power curves for planform-twist variations reflect power required by the rotor. Neither tail rotor power nor accessory power has been added. Coefficients of drag for the blade were incremented by $\Delta C_D = .002$ to account for blade roughness over that of a polished wind-tunnel specimen. This correction has been substantiated by test correlation of measured power (see Figure 6. 1).

Bending moment results represent maximum one-half peak-to-peak flatwise vibratory blade moments. Comparisons with flight test data indicate that this is the major contributor to vibratory blade stress, but it may not correspond to maximum combined stress on the spar section. Study of measured blade vibratory stresses for Sikorsky blades indicates that flatwise, chordwise, and torsional moments combine to give a maximum stress at the back corner of the D-spar section. Shown in Figure 4. 1 is a typical D-spar blade section. Locations of the neutral axis and probable point of maximum vibratory stress have been designated.

A. ROTOR POWER CHARACTERISTICS

Variations in rotor power with change in blade twist and planform are given in Figures 7. 5 through 7. 20. Presented are results for the 16 rotor systems studied. General characteristics noted from these results are summarized schematically in Figure 7. 2, which is presented on the next page.

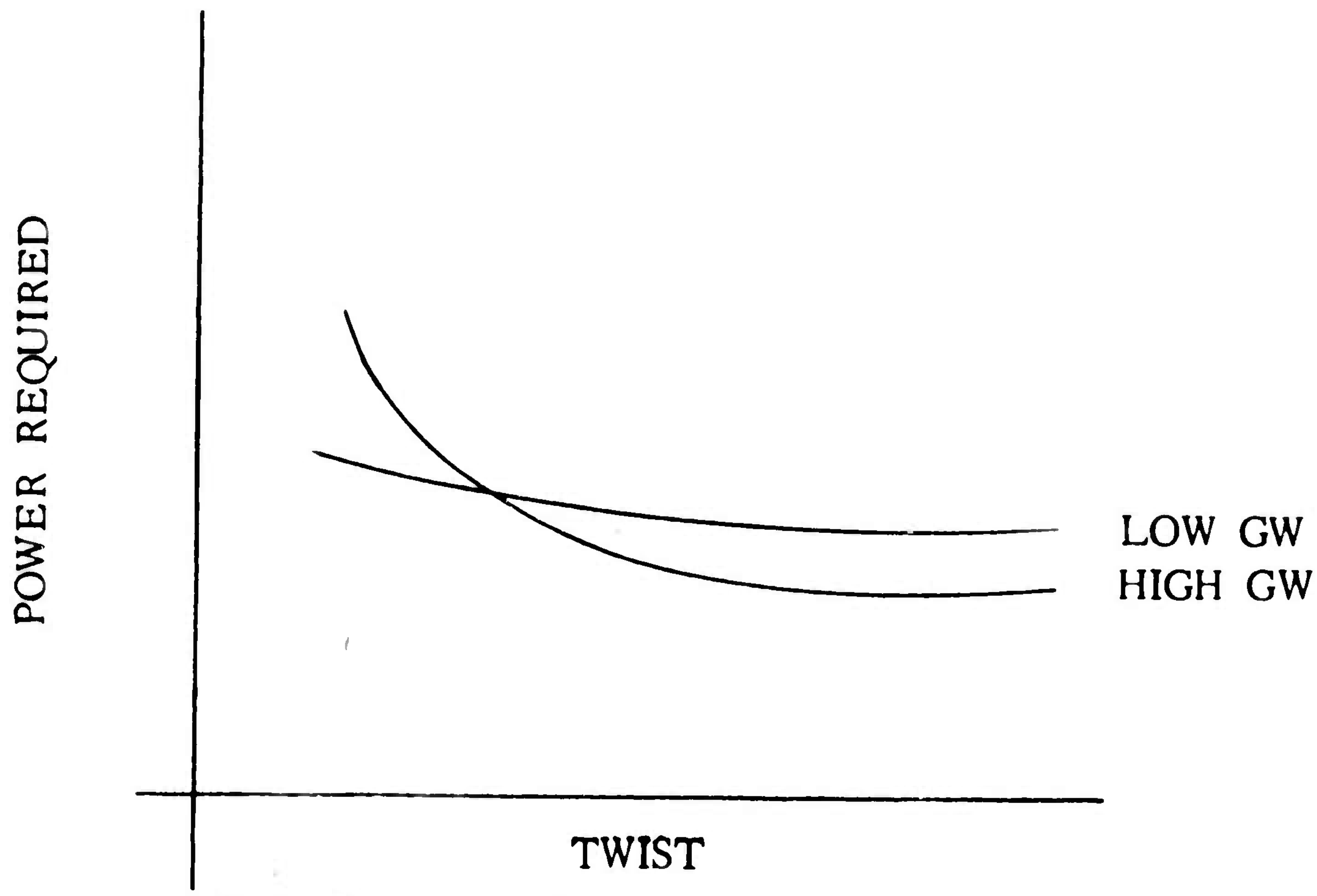


FIG. 7.2 EFFECT OF TWIST ON POWER

Conclusions from study of these characteristics are as follows:

1. There is an optimum blade twist to minimize power for the aircraft considered.

2. The value of twist for minimum power will vary with the aircraft's mission.

3. For the helicopters, optimum twist was found to be in the region of -8 degrees; for the jet compounds, in the region of -4 degrees; and for the winged compounds, in the region of 0 degrees. For winged compounds, variation of power with change in blade twist was found to be small.

With change in blade twist,gradual power variations were noted for the low-gross-weight designs. For the high-gross-weight aircraft, several cases of sharp power gradients were found with twist changes. Power variations were attributed to two effects:

1. There was an outward movement of the steady aerodynamic drag resultant acting on the blade with

decrease in negative blade twist. This is shown by Figure 7. 4, which plots location of resultant aerodynamic thrust and drag vectors with change in blade twist. Results are plotted for the H2 helicopter at 150 knots.

2. Figure 7. 3 shows the variation in magnitude of the resultant drag vector with change in blade twist for the same aircraft. Note that total drag increases as twist becomes more positive or negative about the minimum -4 degree point.

As illustrated by Figure 7. 2, there is a sharper power gradient with increased positive twist than with increased negative twist. Power is determined by the product of drag resultant times distance to center of rotation. With increased positive twist, Figures 7. 3 and 7. 4 indicate that both magnitude and distance of the resultant drag vector will increase, resulting in a sharp power gradient. With increased negative twist, magnitude of the vector increases but its location moves in, giving a more gradual power gradient.

Change in magnitude of the drag resultant with change in blade twist is attributed to the changing time-averaged $^L/_D$ ratio for the entire blade. This results in an increase in drag, since the blade must maintain the same time-averaged lift coefficient independent of twist. The minimum point on the power-twist curve thus corresponds to that twist at which the blade is operating at its optimum time-averaged $^L/_D$ ratio.

B. FLATWISE VIBRATORY MOMENT CHARACTERISTICS

Presented in Figures 7. 21 through 7. 36 are maximum flatwise vibratory bending moments versus twist for the four blade planforms. Results are given for both rigid and articulated rotor systems and follow the schedule of Tables 2. 2, 2. 7, and 2. 8. It is interesting to note that the planform order from lowest to highest bending moments is fairly consistent between both gross weights, and rigid and articulated systems. For both gross weight machines, highest blade bending moments were for the relatively stiff 3:1 planform blade; lowest were for the nonlinear blade. The relatively flexible 1:2 blade, while showing low moments, would present design problems as a rigid rotor.

With variation in blade twist, flatwise vibratory moments followed general characteristics as shown by Figure 7. 37, schematically below:

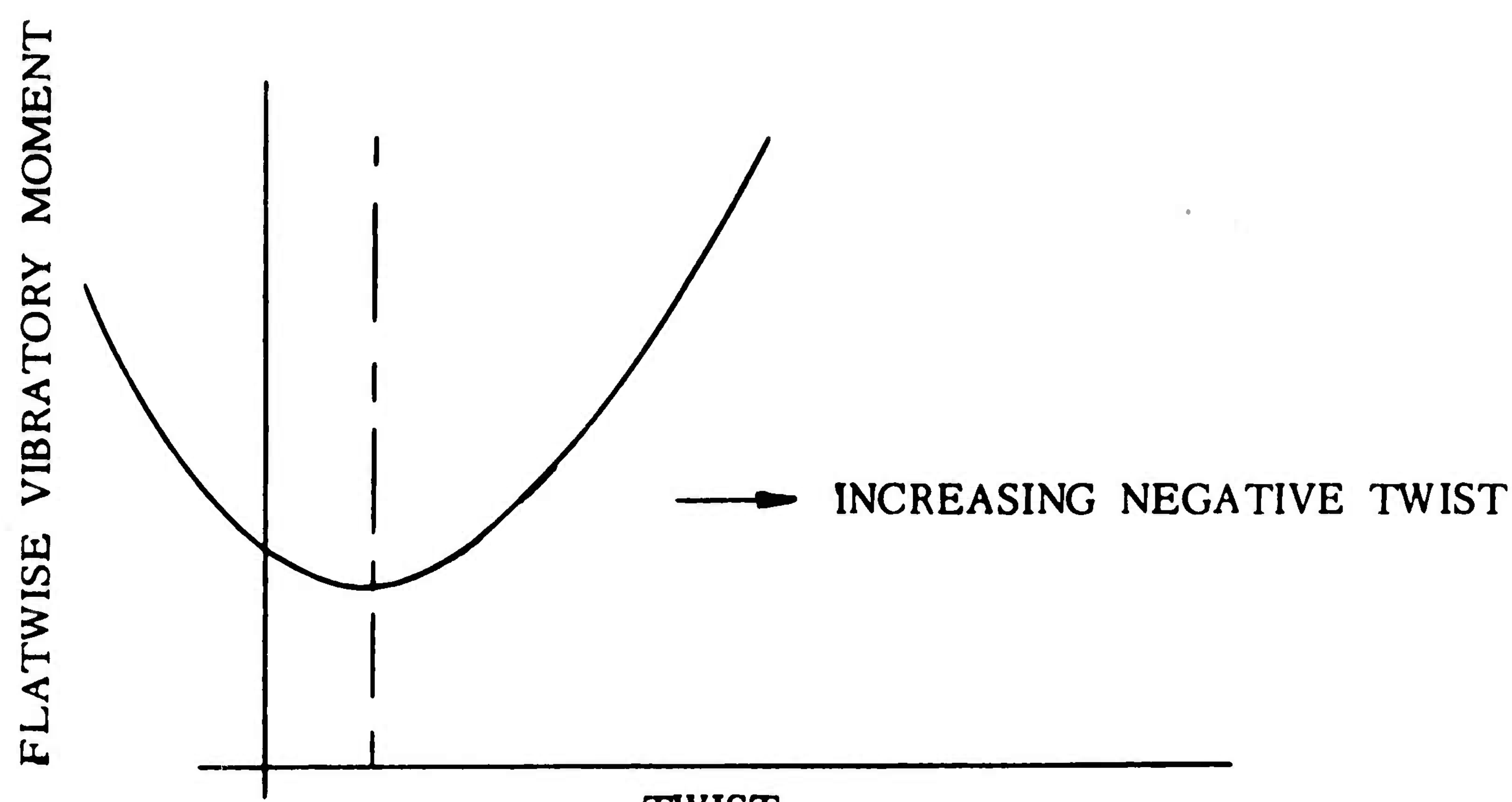


FIG. 7.37 EFFECT OF TWIST ON MAXIMUM BENDING MOMENT

From the curve it can be seen that there is a minimum vibratory moment for each blade design. For blade designs considered in this investigation, values of twist for minimum vibratory moment ranged from +2 to -2 degrees.

Shown in Figure 7.39 are plots giving the radial distribution of one-half peak-to-peak stress for a typical articulated-rotor helicopter. Plots are presented for the H2 helicopter at 150 knots for a 1:1 planform blade at twists of 0, -4, -8, and -16 degrees respectively. Curves are typical of articulated blades with the maximum vibratory stress occurring at about two-thirds blade radius. Also, note that location of the critical blade station changes with change in blade twist.

Corresponding plots of the calculated time history of bending moment for the 0, -8, and -16 degree twists are given in Figure 7.40. Observe that maximum negative bending stress occurs on the advancing blade at about ψ = 120 degrees. Also, note that the negative stress value at this azimuth is extremely sensitive to change in blade twist. Study of Figure 7.40 supports the conclusion that increase in vibratory stress with increase in negative twist is primarily caused by increased negative bending moment on the advancing blade.

This conclusion is further supported by study of the aerodynamic load distribution on the advancing blade. Figure 7.41 plots the radial distribution of airloads on the advancing blade (ψ = 90°) for 0, -8, and -16 degree twists. Note the appearance of negative lift regions on outboard blade sections as twist increases from 0 to -16 degrees. These outboard lift regions are responsible for the increased negative bending moments associated with larger negative twist. In turn, negative airloads are related to pitch trim requirements as described below:

1. Variation in blade control angle (reference r/R=0.70) with change in blade twist is plotted in Figure 7.43). Results indicate that there is only a small change in collective pitch with blade twist since collective controls the thrust requirement, and this has been held constant for all twists. Also, observe that retreating blade control angle (ψ =270°) remains fairly constant with twist, and is about that of the section stall angle. With negative twist, this means that blade element angles outboard of .70R are less than the control angle, while those inboard are higher. Or with increased negative twist, point of application of the resultant lift on the retreating blade moves in, giving a corresponding decrease in thrust moment.

2. Decrease in thrust moment with increased negative twist is plotted in Figure 7.44 for both advancing (ψ =90°) and retreating (ψ =270°) blades. Thrust moment on the retreating blade was found to be close to the maximum attainable at this azimuth. Results showed that both halves of the rotor disk are attempting to balance total lift equally between them. If the control angle at ψ =270° degrees is increased above the value plotted, outboard blade sections have higher angles of attack, move further into stall, and lose lift. With decreasing control angle at 270 degrees, outboard blade angles decrease and there is reduced lift on the blade.

3. The requirement for rotor trim in the calculations was that there be no pitching or rolling moments in fixed

coordinates. Therefore, associated with decreased thrust moment on the retreating blade, there must be a corresponding decrease in thrust moment on the advancing blade as shown by Figure 7. 44. At the same time, total thrust on the advancing blade increases to compensate for less of lift on the retreating blade. Here, advancing blade inboard elements must increase lift to offset negative lift on outboard sections. The rotor fails to meet trim requirements when inboard sections of the advancing blade can no longer make up for lift lost on the retreating side. These trends can be seen in the airload distributions on advancing and retreating blades for various blade twists as shown by Figures 7. 41 and 7. 42.

4. In conclusion, increased negative twist unloads the retreating blade and loads the advancing blade. Due to pitch trim requirements, the advancing blade cannot carry the additional lift on the most efficient outboard panels. Instead, it must move the lift well inboard. The resulting one-per-rev load dissymmetry is the aerodynamic cause of increased blade vibratory stress with increased negative twist.

Figures 7. 45 through 7. 47 present effects of blade twist on combined aerodynamic and inertia loads, and resulting blade deflections and moments. Plotted in Figures 7. 45 and 7. 46 are radial distributions of aerodynamic (shown dotted) and inertia loading for 0 and -8 degree twist blades for the H2 helicopter. Load distributions are given for azimuth positions of maximum negative and positive bending stress. The contribution of blade response to total applied load is shown by the difference between applied and aerodynamic loadings. Figure 7. 47 shows schematically corresponding outboard deflections and moments for each blade at the azimuth position of maximum negative stress. Note the larger deflections of the 0 degree twist blade due to more heavily loaded blade outboard sections. Also, note the 20% radius shift in location of the critical blade station. Observe that both blades have about the same positive moment due to applied flatwise loading, but negative moment of the -8 degree twist blade is greater due to centrifugal forces.

So far, discussion has centered on understanding increased vibratory stress with increased negative twist. Figure 7. 37, which gives general characteristics of stress-twist variations, also shows increased stress as twist becomes more positive.

Analysis of results indicates that this is due to increased positive moment on the retreating blade rather than increased negative moment on the advancing blade. As twist becomes more positive, the retreating blade takes on more load. In other words, minimum on the stress-twist curve of Figure 7. 37 is that point at which best load sharing is achieved as related to stress. As twist becomes further positive, the retreating blade moves into stall. At this point the advancing blade once again assumes the additional load.

Results of stress-twist variations for rigid rotor designs showed aerodynamic trends similar to articulated systems, but as expected, resulting blade responses were considerably different. Given in Figures 7. 48 and 7. 49 are the radial distributions of airloads for 0 and -8 degree twist blades for the H2-R. Results are plotted for both advancing ($\psi = 90°$) and retreating blades ($\psi = 270°$). Comparison of these plots with those of Figures 7. 41 and 7. 42 for the equivalent articulated blade indicates little difference in airload distribution.

Presented in Figure 7. 50 are azimuth histories of bending moment at the critical blade station for the same rigid blade. Comparison with azimuth plots (Figure 7. 40) for an equivalent articulated blade shows widely different harmonic contents. Variations are attributed to differences in modal response, differences in aerodynamic damping, and wide separation of location of critical blade station. For the H2-R 0-degree twist blade, one-half peak-to-peak bending moment is defined by the difference between moments at $\psi = 160°$ and $\psi = 260°$. Radial distribution of vibratory bending moments is given in Figure 7. 38. For rigid blades, maximum vibratory moment generally occurs at the blade root.

C. EDGEWISE VIBRATORY MOMENTS CHARACTERISTICS

Variations in edgewise vibratory moments with twist and planform changes are presented in Figures 7. 51 through 7. 54. Shown are results for the H1, H1-R, H2, and H2-R helicopters. There is a trend with twist similar to that observed for flatwise bending moments (see Section 7-B). Note that edgewise moment minimum values occur at higher negative twist than for corresponding flatwise minimums. There are several significant variables which affect blade edgewise moments. These include:

1. Edgewise Tuning for Rigid Rotors

Lockheed's design criteria (Section 4) take into account the high sensitivity of edgewise moment to the blade's first inplane bending frequency. Proximity of this mode to one-per-rev results in excessively high chordwise moments at the blade root. Here, blade resonance becomes more critical than for flatwise moments since there is little aerodynamic damping to attenuate amplification. Figure 10. 4, which plots the effect of tip weight, clearly indicates this sensitivity for a rigid blade. The sharp continuous reduction shown for edgewise stresses is due to detuning the first edgewise mode. The rigid blade in this case (aspect ratio = 18) was designed for $\omega_1^E = .65\,\Omega$. Added weight brings this mode further below one-per-rev.

2. Lag Damper Characteristics for Hinged Blades

For the investigation, a linear lag damper constant was assumed in the analysis. This provides a damping moment in proportion to the blade angular hunting velocity. Actual blade dampers used for conventional helicopters are difficult to simulate analytically. Here, damping is provided by hydraulic fluid passing through an orifice. This results in damping proportional to velocity squared. Also, these dampers often provide a relief valve to limit blade stresses, which introduces a sharp cutoff at a specified damper force. Detailed correlation of calculated edgewise moments with flight test requires that such effects ultimately be taken into account.

3. Blade Counterweights

Mass-balancing blade counterweights (see Figure 4. 1) were considered as being attached to the blade section but nonstructural in the analytic study. In actual practice, weights may be restrained against radial motion by a plate at the blade tip. A concentrated force is then produced forward of the elastic axis at the tip. This results in a large steady edgewise bending moment being applied to the blade.

D. PLANFORM CHARACTERISTICS

Variation in blade planform results in two significant effects. There is a change in radial distribution of airload due to change in chord with blade radius. Also, there is a shift in blade response characteristics due to mass and stiffness changes associated with chord variation. These are discussed separately as follows.

1. Aerodynamic Loading

Developed below are equations which relate blade twist and planform. They give the twist required on a 1 : 1 tapered blade to reproduce the blade loading on a blade of arbitrary chord and twist distribution.

Given: Lift per unit length $\frac{dL}{dr}(r\psi)$

Blade twist $\beta_T(r)$

Blade chord $C(r)$

Then:

$$\frac{dL}{dr}(r\psi) \sim \frac{1}{2}\rho V^2(r\psi) \frac{dC_L}{d\alpha} \alpha(r\psi)\, C(r) \quad \ldots\ldots\ldots \quad (1)$$

Setting up a ratio for the blades:

$$1 = \frac{\frac{dL}{dr}(r\psi)}{\frac{dL}{dr}(r\psi)_{11}} = \frac{\frac{1}{2}\rho V^2(r\psi) \frac{dC_L}{d\alpha} \alpha(r\psi)\, C(r)}{\frac{1}{2}\rho V^2(r\psi) \frac{dC_L}{d\alpha}_{1:1} \alpha(r\psi)_{1:1}\, C_{11}} \quad \ldots\ldots\ldots \quad (2)$$

If airfoil sections are the same for each blade:

$$\frac{dC_L}{d\alpha}_{1:1} = \frac{dC_L}{d\alpha} \quad \ldots\ldots\ldots \quad (3)$$

Or, the required angle-of-attack distribution (uniform blade) is:

$$\alpha_{1:1}(r\psi) = \frac{C(r)}{C_{11}} \alpha(r\psi) \quad \ldots\ldots\ldots \quad (4)$$

Also:

$$\alpha(r\psi) = \theta + \phi - \beta_T \quad \ldots\ldots\ldots \quad (5)$$

But for equivalence of airloads:

$$(\theta + \phi)_{1:1} = \theta + \phi \quad \ldots\ldots\ldots \quad (6)$$

And required twist for the uniform blade is:

$$\beta_T(r)_{1:1} = (\theta + \phi)\left[1 - \frac{C(r)}{C_{11}}\right] + \frac{C(r)}{C_{11}} \beta_T(r) \quad \ldots \quad (7)$$

Equation 7 shows that equivalence of twist and planform is not only determined by chord ratios but also depends upon $(\theta+\phi)$. Values $(\theta+\phi)$ are functions of both azimuth, ψ, and forward speed, V. However, preliminary results of these studies indicate that the azimuth variation may not be significant in matching low harmonics of airloads for twist-planform similarity.

This is shown by Figures 7. 55 through 7. 57. Plotted in Figure 7. 55 is the change in location of the resultant steady thrust vector with change in blade twist for a 1 : 1 planform or uniform blade. Results are presented for the H2 helicopter at 150 knots. Also shown on the plot are locations of the thrust vector for -8° twist, 1 : 2 and 3 : 1 planform blades. The 1 : 2 taper, -8° twist blade is noted to be nearly equivalent to a 1 : 1 taper, -6. 5° twist blade. Similarly, the 3 : 1 taper, -8° twist blade compares closely to a 1 : 1 taper, -10. 8° twist blade.

The equivalence is further reflected in calculated control angles at this airspeed. Figure 7. 56 plots variation in collective and cyclic pitch blade angles versus blade twist for the uniform blade. Also shown on this plot is corresponding control angle for the 1 : 2 planform blade. Note that the twist equivalence value for this blade is about the same (-6. 5°) as on the thrust vector location plot.

Even more interesting is the near match of steady and first harmonic blade loading. This is shown by Figure 7. 57. Compared are the load distributions for a -6° twist, 1 : 1 planform blade and the -8° twist, 1 : 2 planform blade. (The -6° twist, 1 : 1 planform blade was the nearest parametric data point to the selected -6. 5°, 1 : 1 blade, which had been run in the study.) Note that not only do steady airload distributions agree, but also both sine and cosine first harmonic distributions are approximately the same.

2. Blade Response

While planform and twist can be related to determine equivalent airload distributions, the resulting blade responses will differ. This is due to changes in blade stiffness (weight held constant) associated with change in chord. Table 2. 10 compares section moduli and curvatures for the 1 : 1 (-6°) and the 1 : 2 (-8°) blades, which were noted to have similar airload distributions (see 1, above).

TABLE 2.10

STRUCTURAL COMPARISON OF 1 : 2 PLANFORM
WITH EQUIVALENT TWIST BLADE

A/C	M_F	I_{crit}	I/I_{st}	Y/Y_{st}	M/M_{st}
1 : 1 -6°	19939.	5.80	1.0	1.0	1.0
1 : 2 -8°	22816.	4.91	.846	1.35	1.145

Observe that stiffness at the critical blade station is 15% less for the 1 : 2 planform (-8°) blade. This leads to 35% higher curvature with a resulting 15% higher vibratory bending moment at that blade station.

E. BLADE MOTIONS

Shown in Figure 7.58 are typical motions of rigid and articulated blades in high-speed flight. Given are results for the H1 and H1-R rotor systems at 150 knots. Deflection curves for the -8 degree twist, 1 : 1 planform blades, rigid and articulated, are plotted at 60-degree azimuth intervals. Curves shown represent variations about blade steady displacements, which are plotted for each aircraft in Figure 7.59. Similarity of steady blade responses is due to the selected value for the rigid-rotor precone angle. This was based on the steady response of the articulated blade.

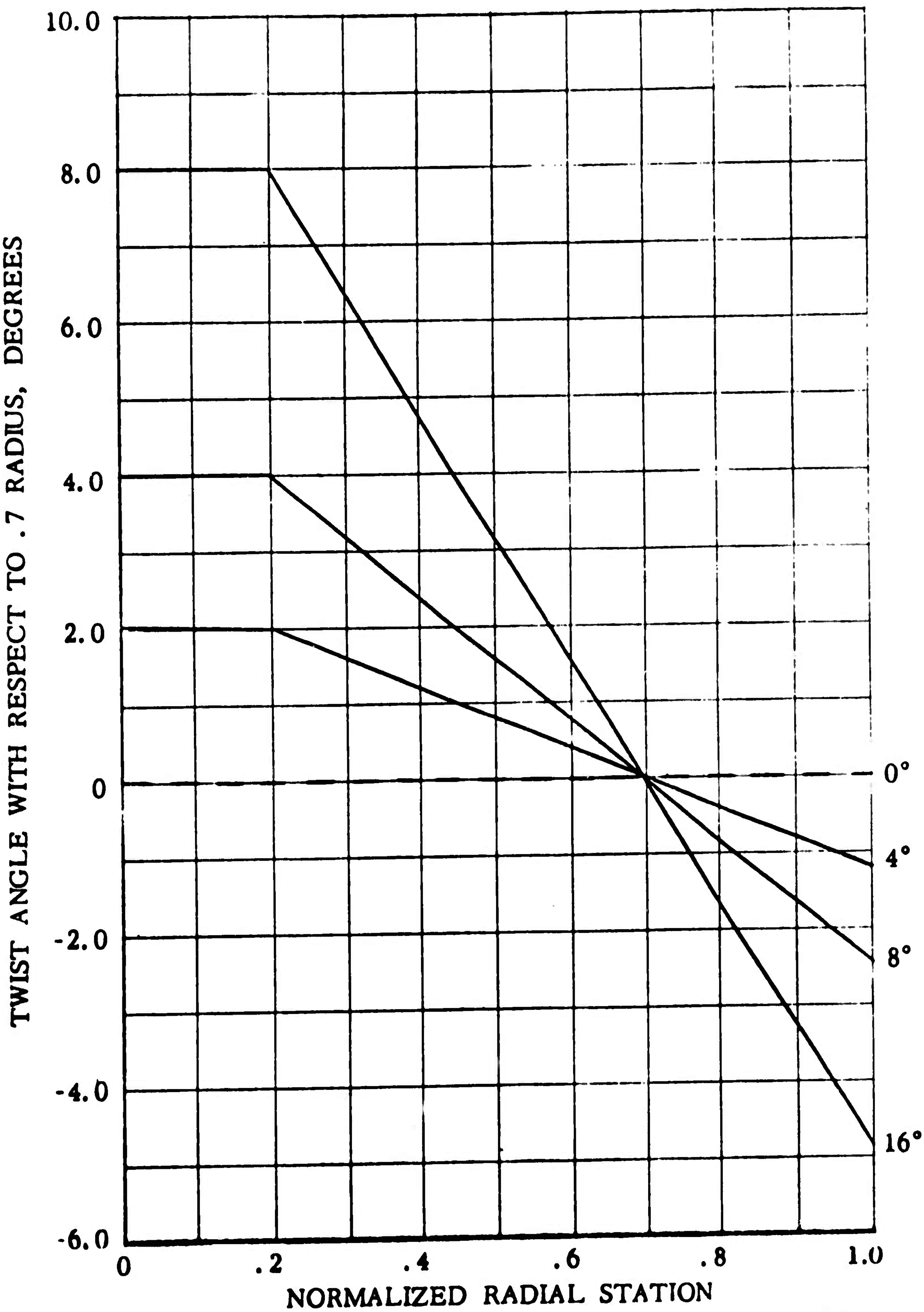


FIG. 7.1 RADIAL DISTRIBUTION OF BLADE TWIST

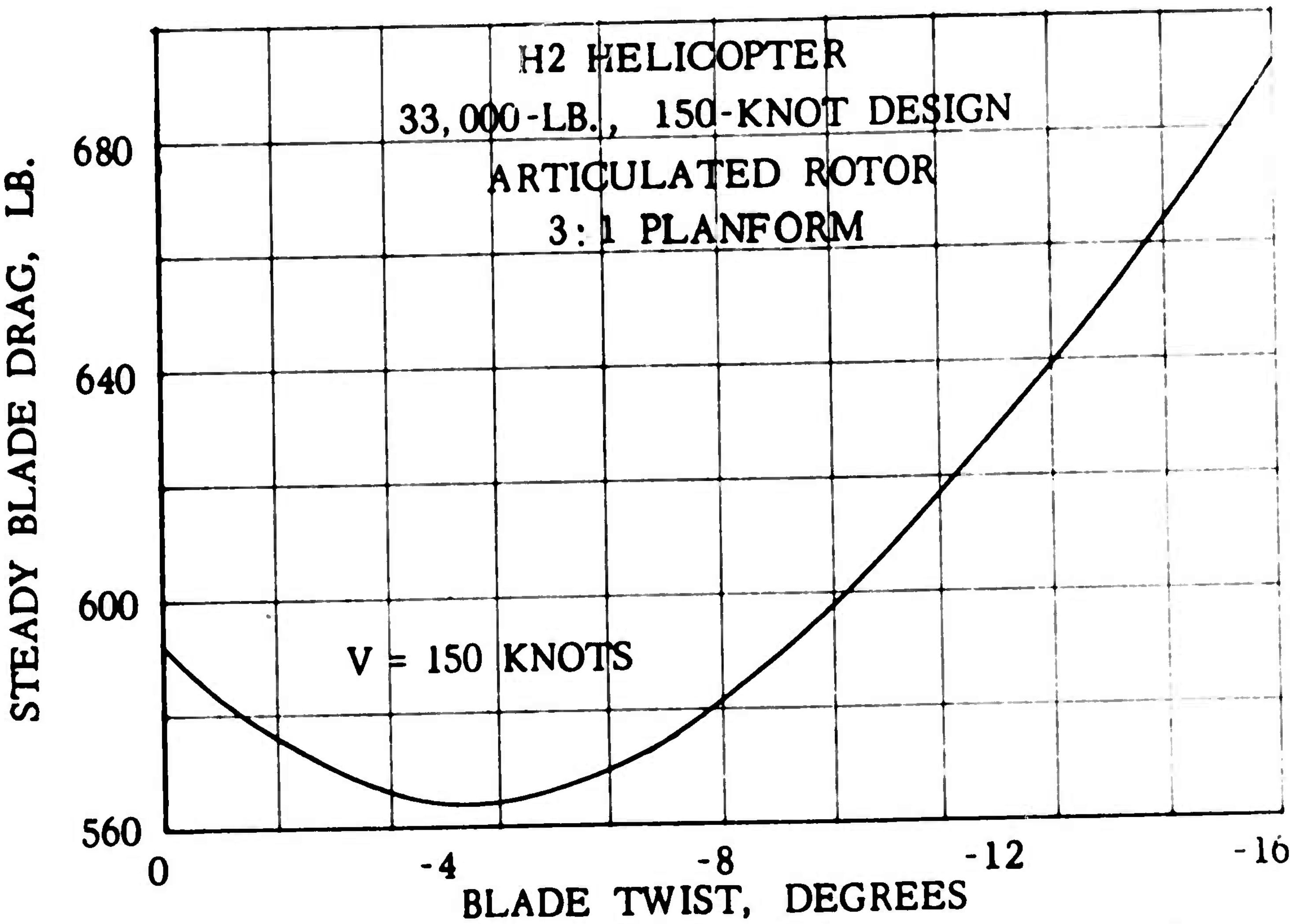


FIG. 7.3 CHANGE IN BLADE DRAG WITH TWIST

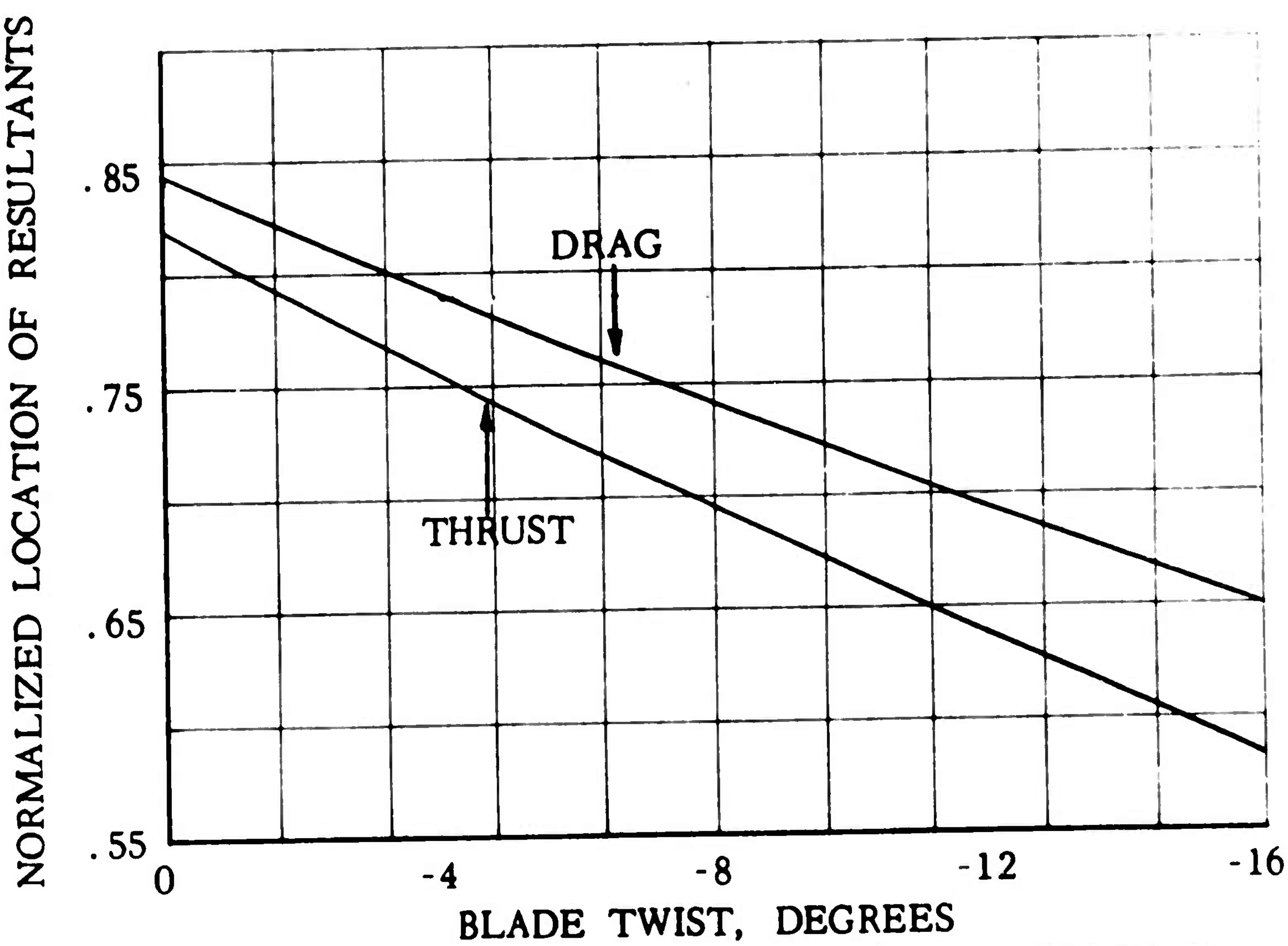


FIG. 7.4 CHANGE IN LOCATION OF RESULTANT DRAG AND THRUST WITH TWIST

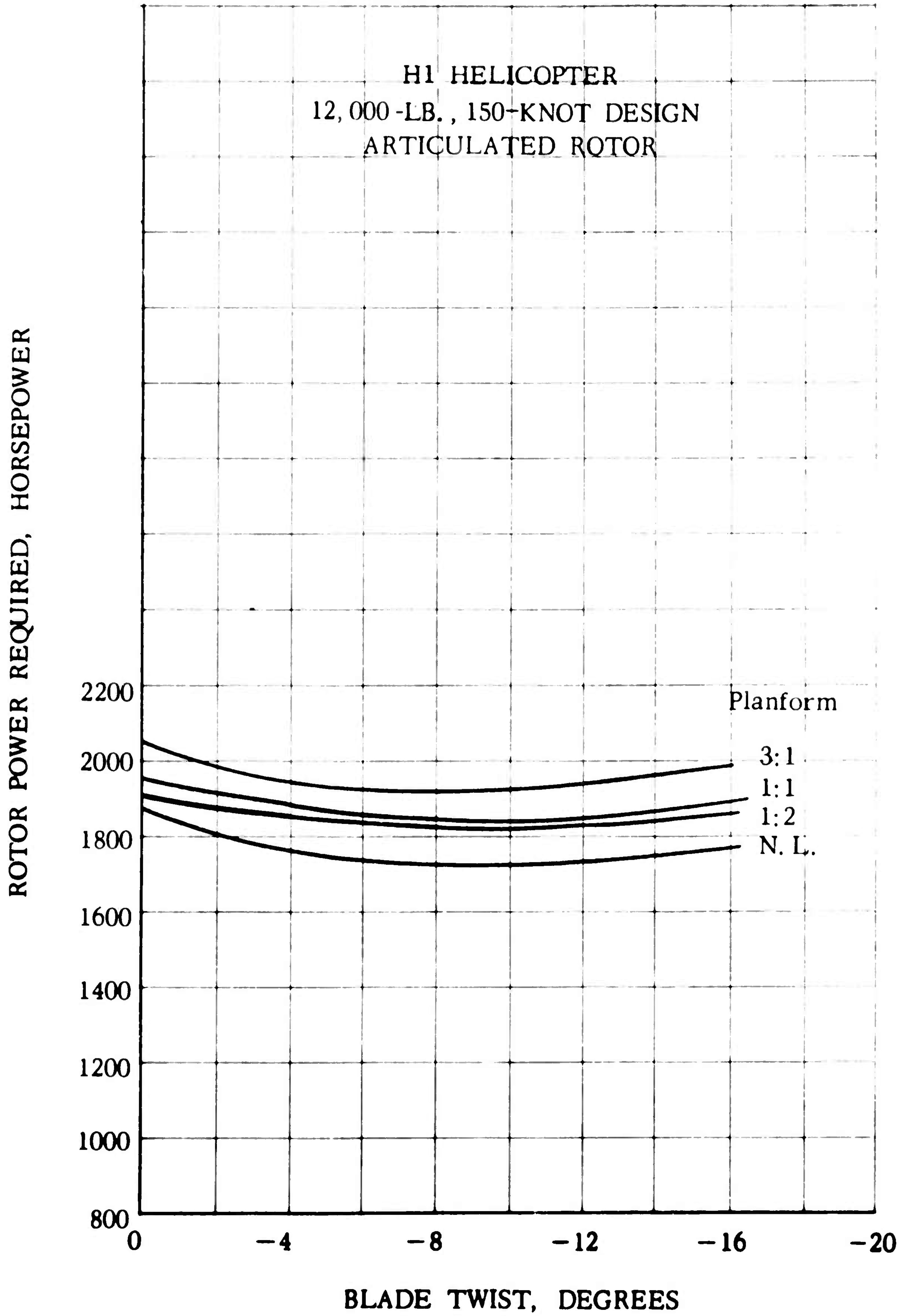


FIG. 7.5 CHANGE IN POWER WITH BLADE TWIST

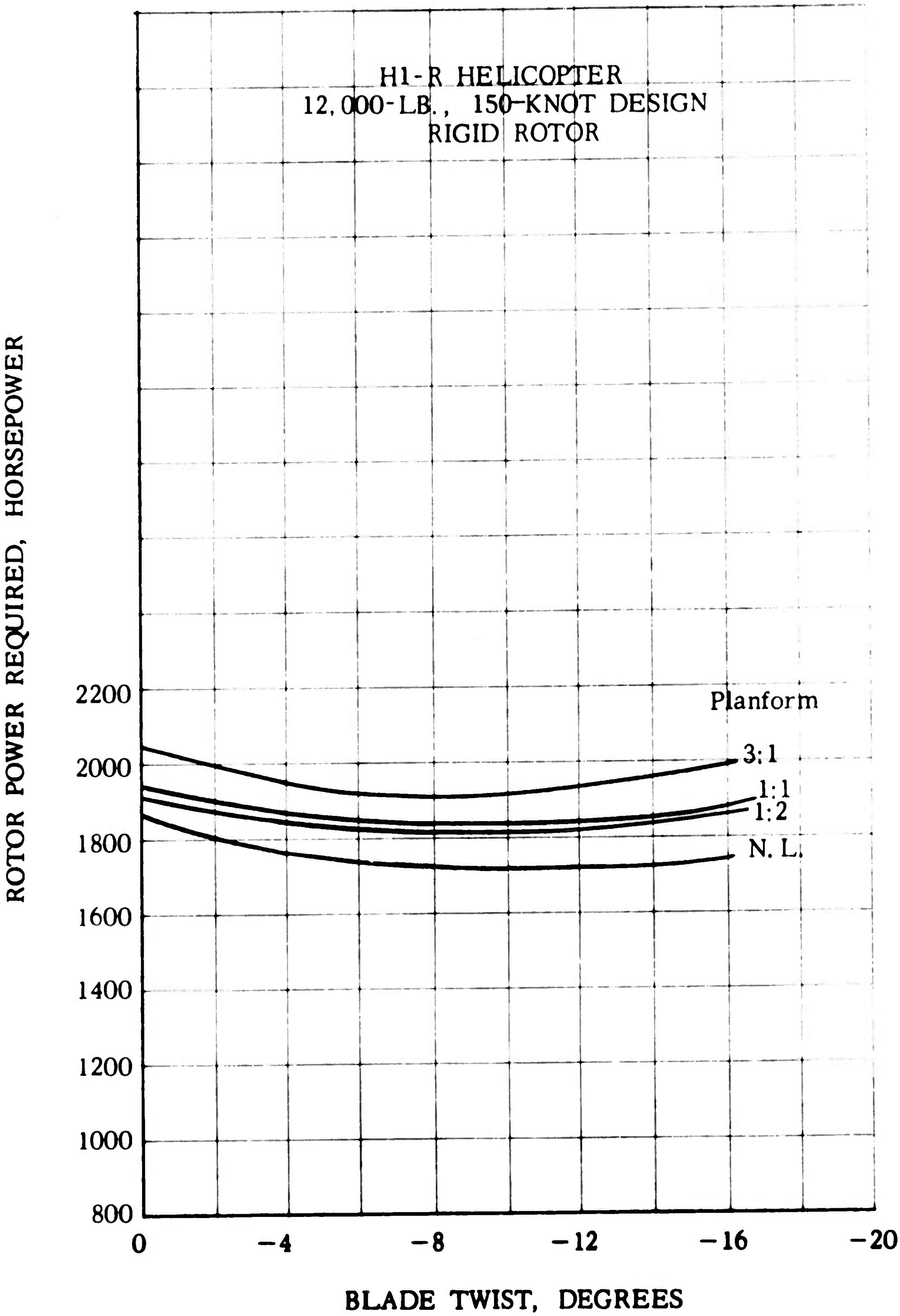


FIG. 7.6 CHANGE IN POWER WITH BLADE TWIST

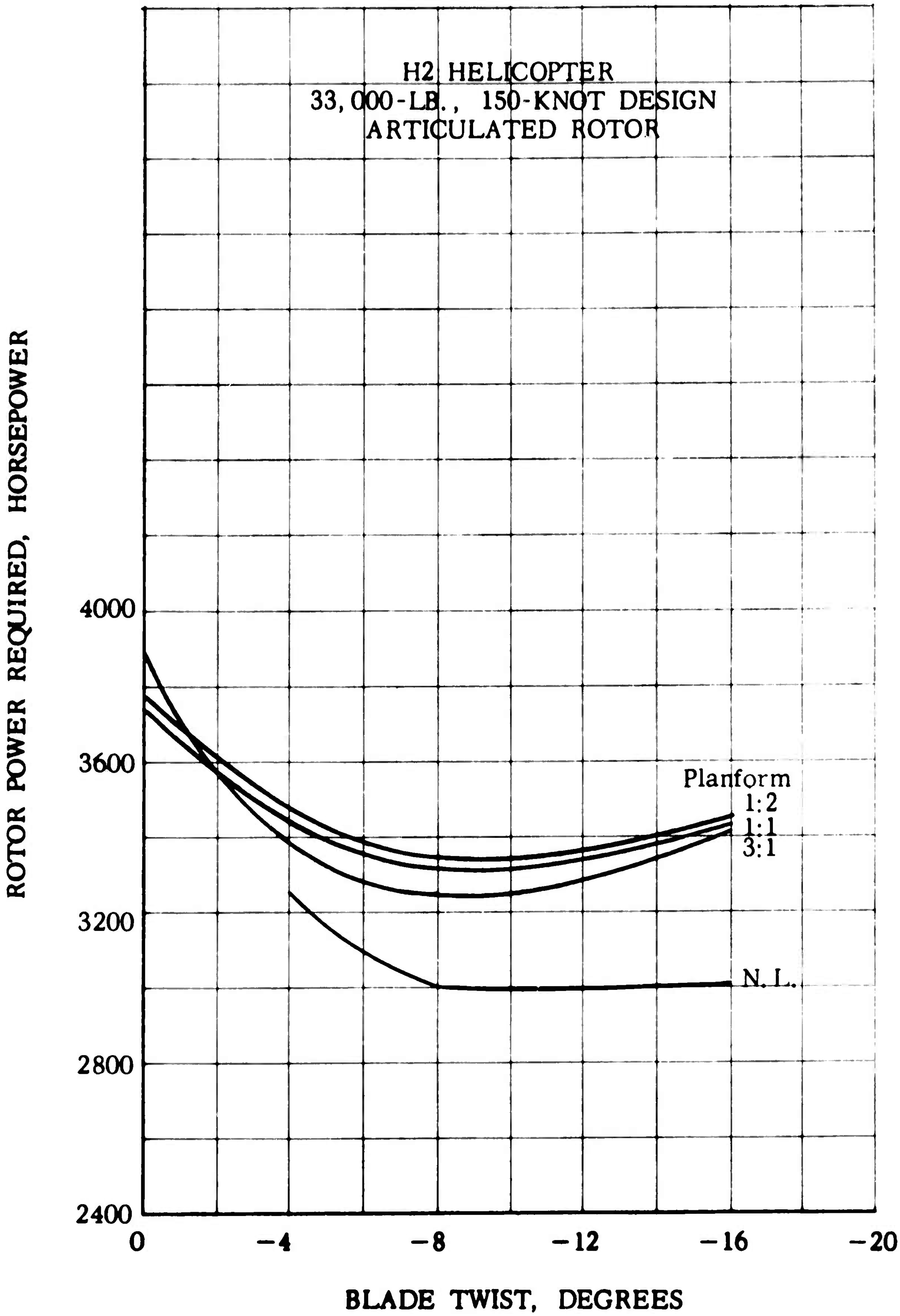


FIG. 7.7 CHANGE IN POWER WITH BLADE TWIST

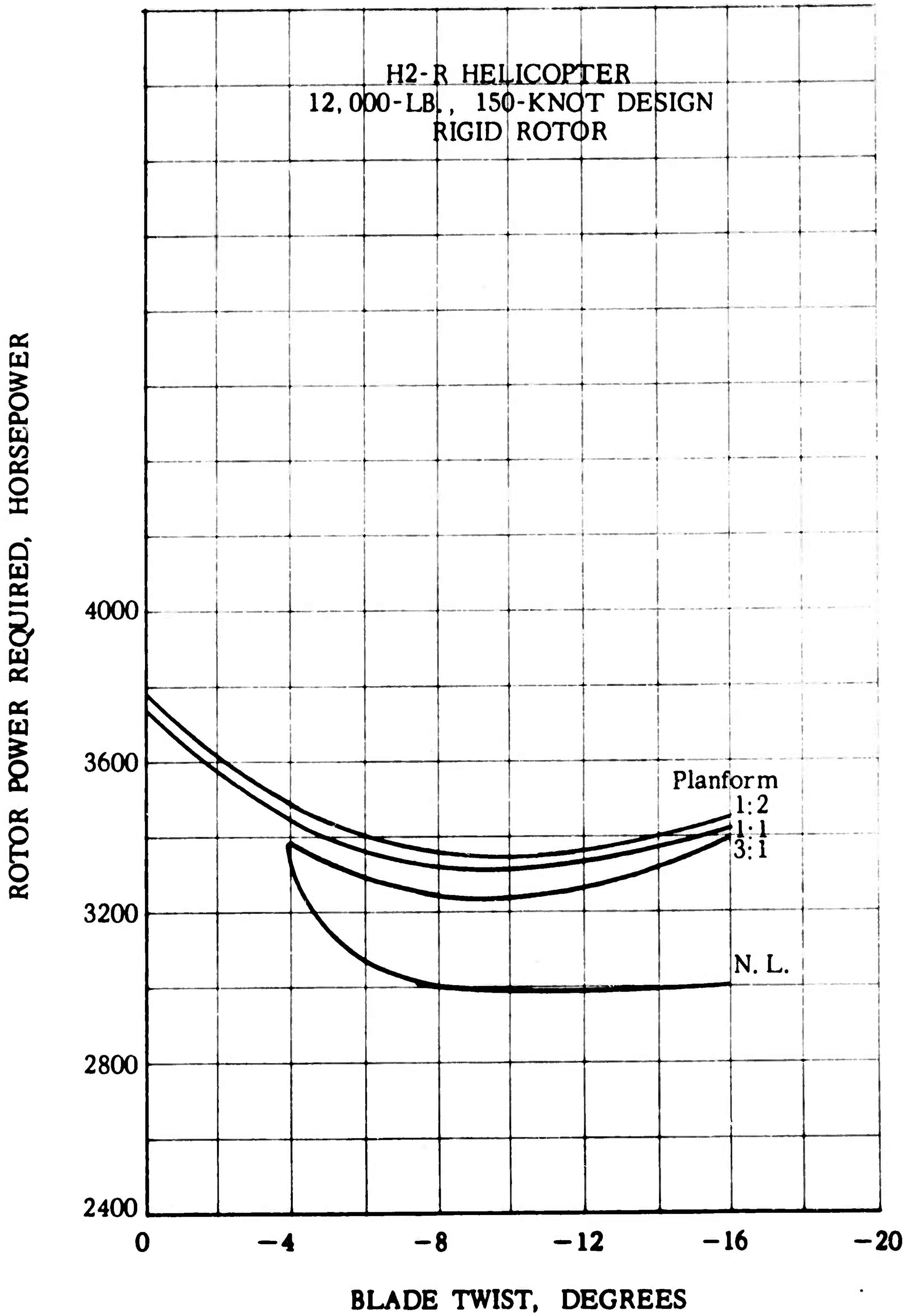


FIG. 7.8 CHANGE IN POWER WITH BLADE TWIST

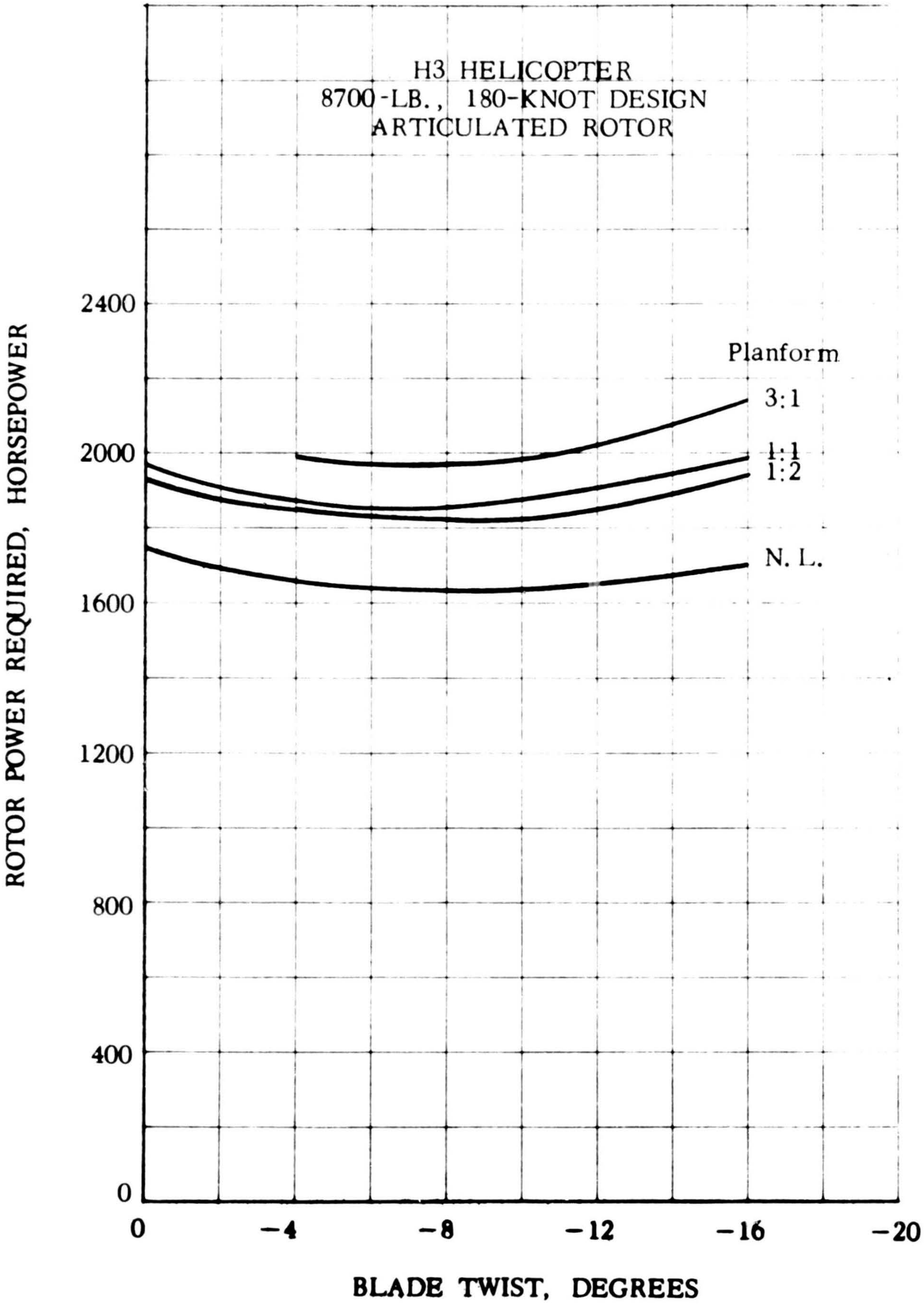


FIG. 7.9 CHANGE IN POWER WITH BLADE TWIST

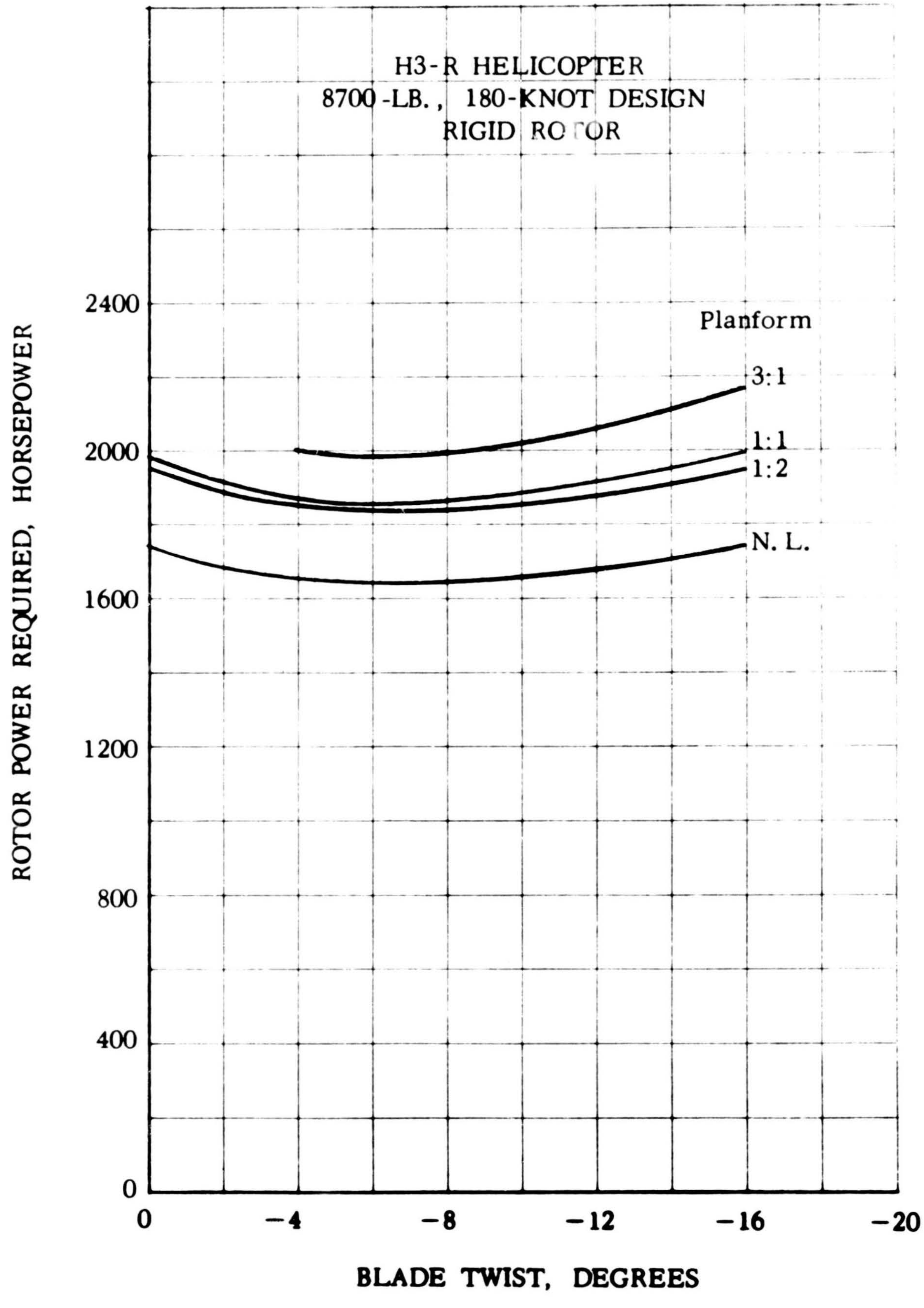


FIG. 7.10 CHANGE IN POWER WITH BLADE TWIST

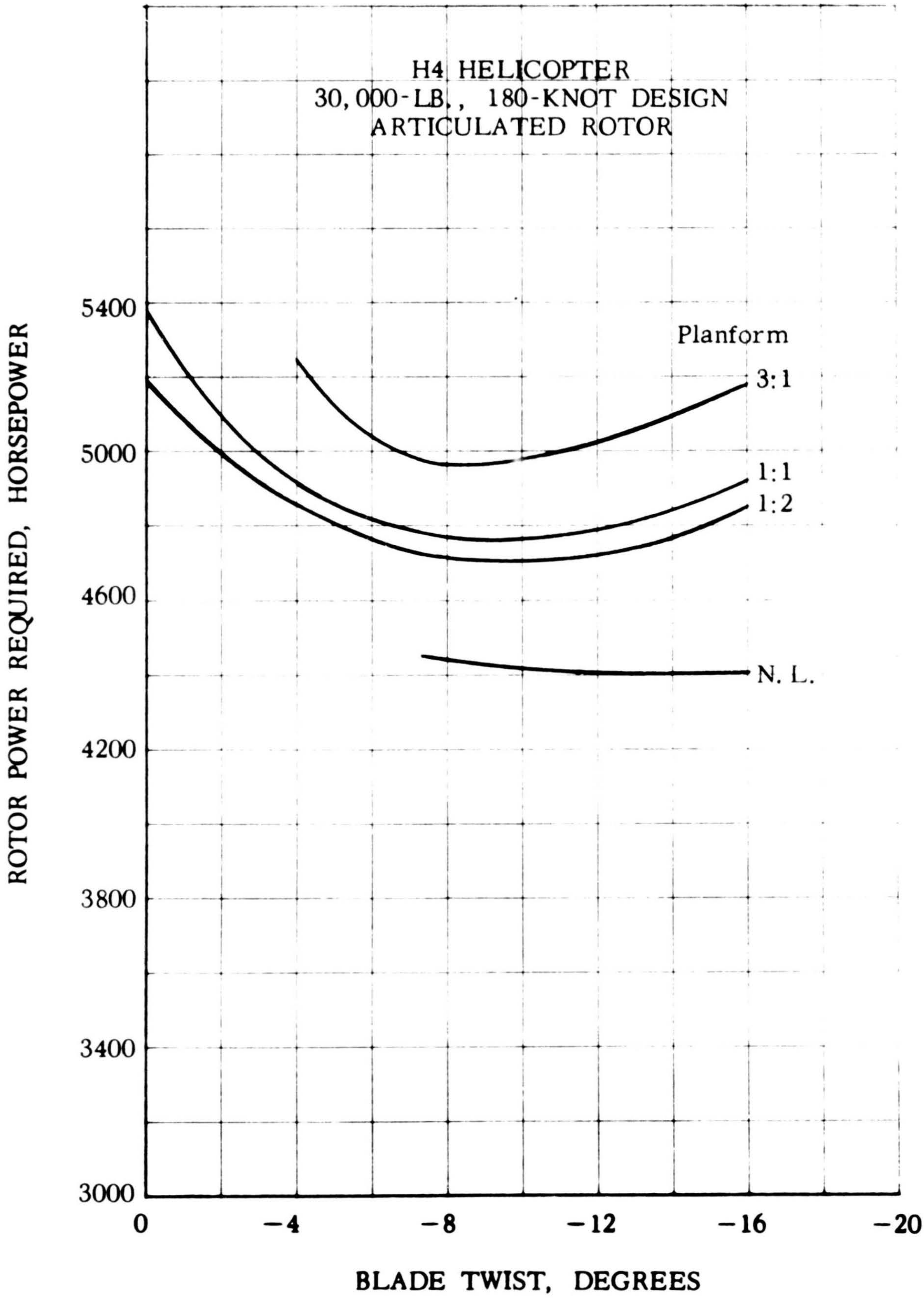


FIG. 7.11 CHANGE IN POWER WITH BLADE TWIST

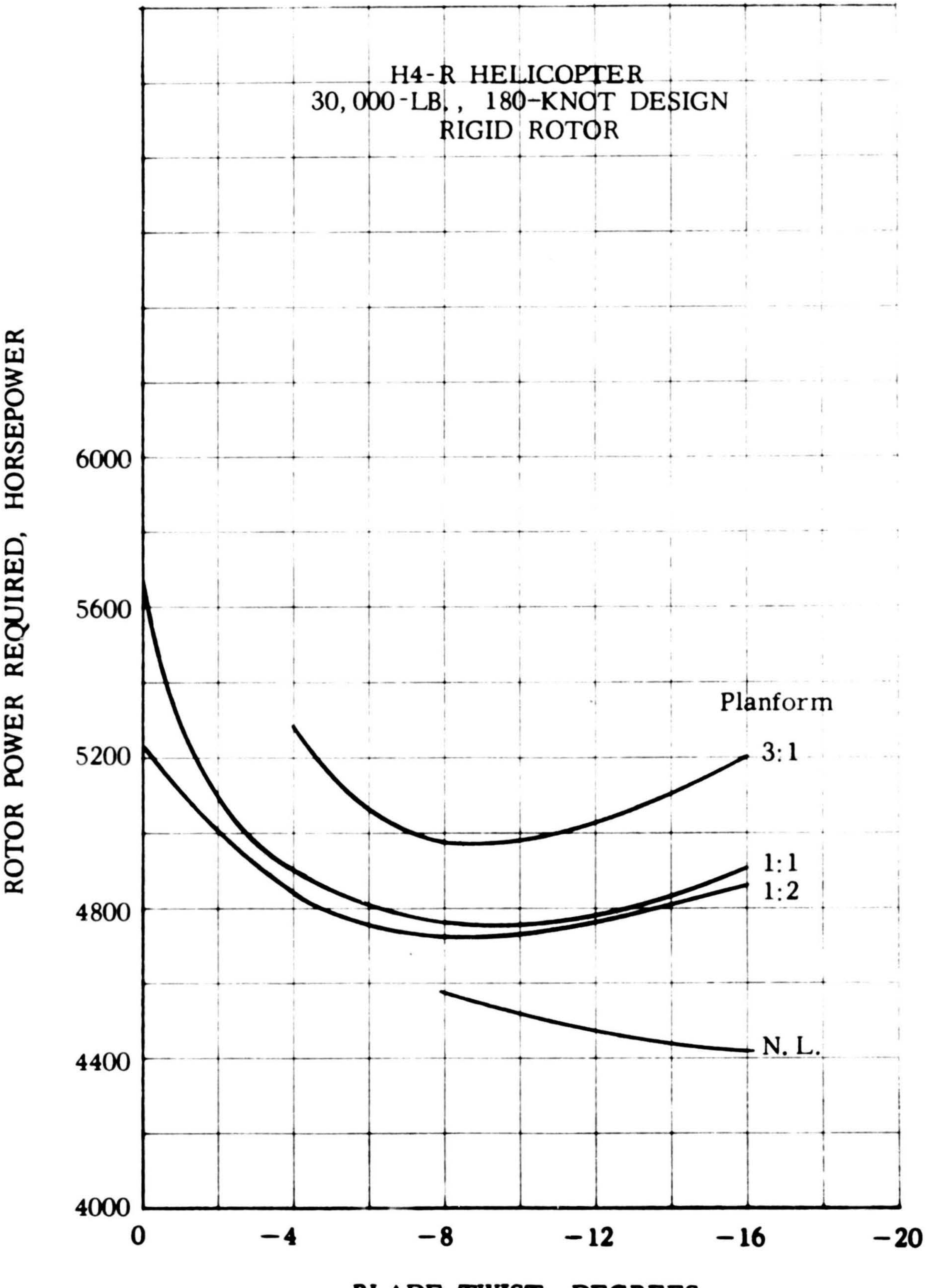


FIG. 7.12 CHANGE IN POWER WITH BLADE TWIST

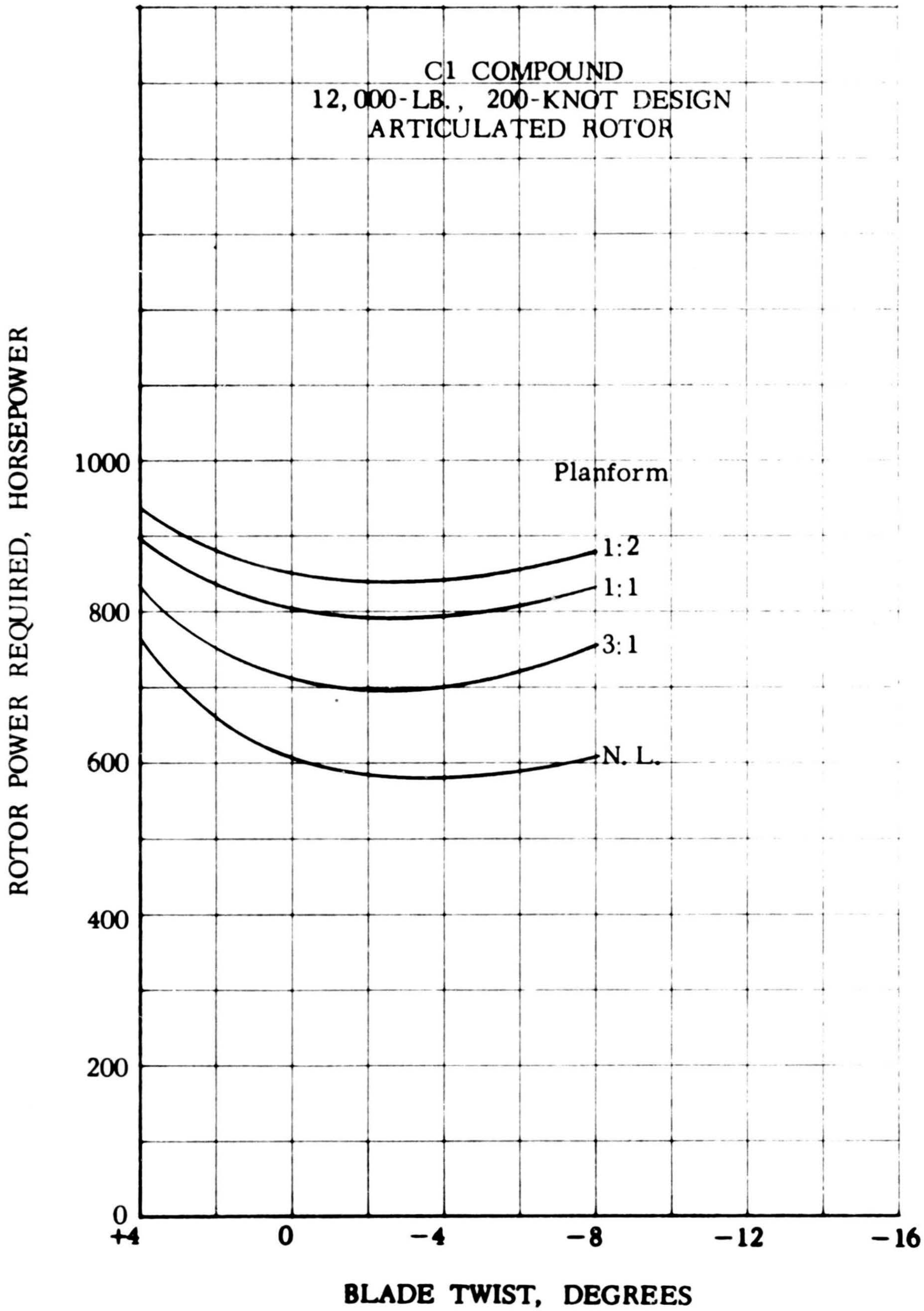


FIG. 7.13 CHANGE IN POWER WITH BLADE TWIST

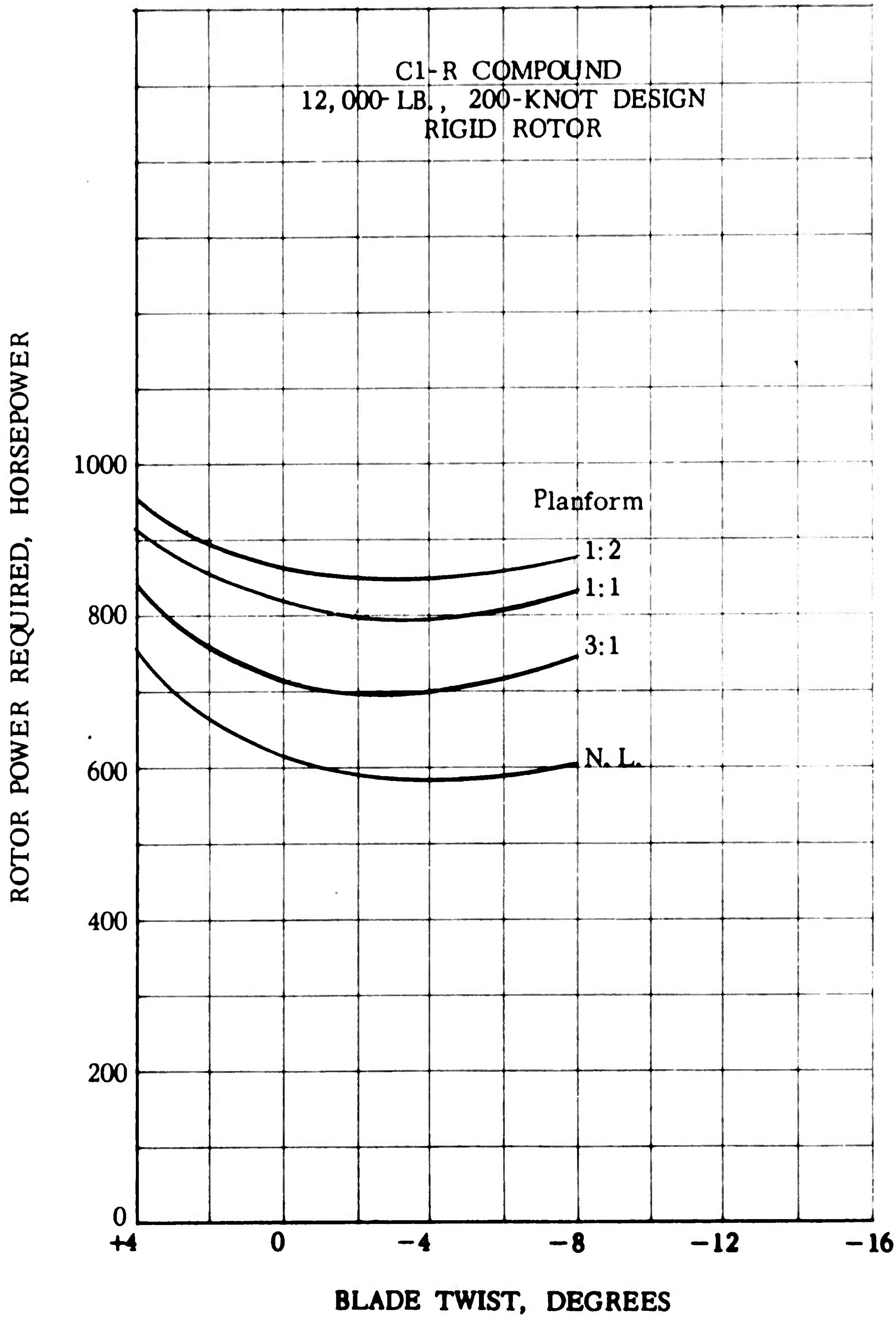


FIG. 7.14 CHANGE IN POWER WITH BLADE TWIST

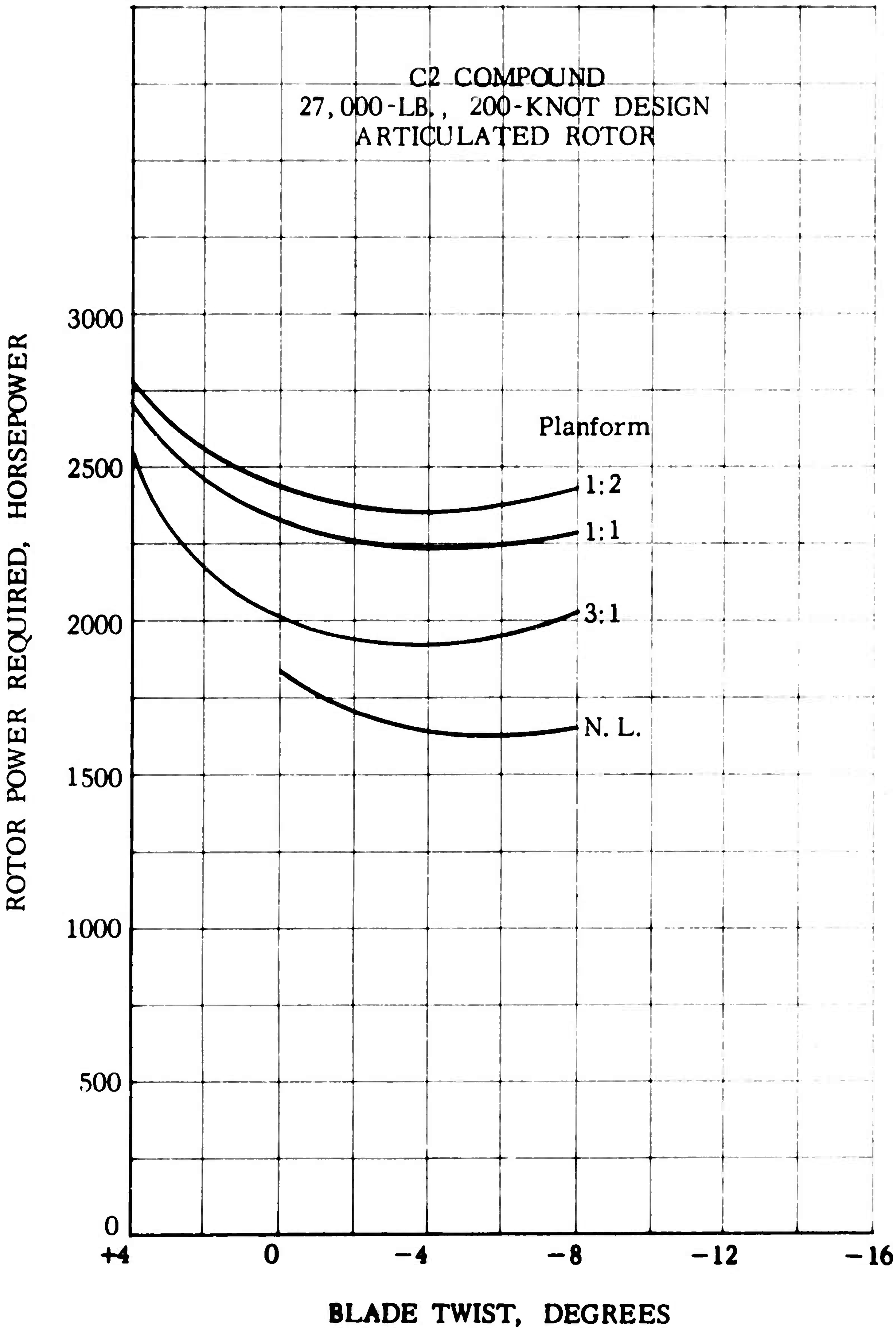


FIG. 7.15 CHANGE IN POWER WITH BLADE TWIST

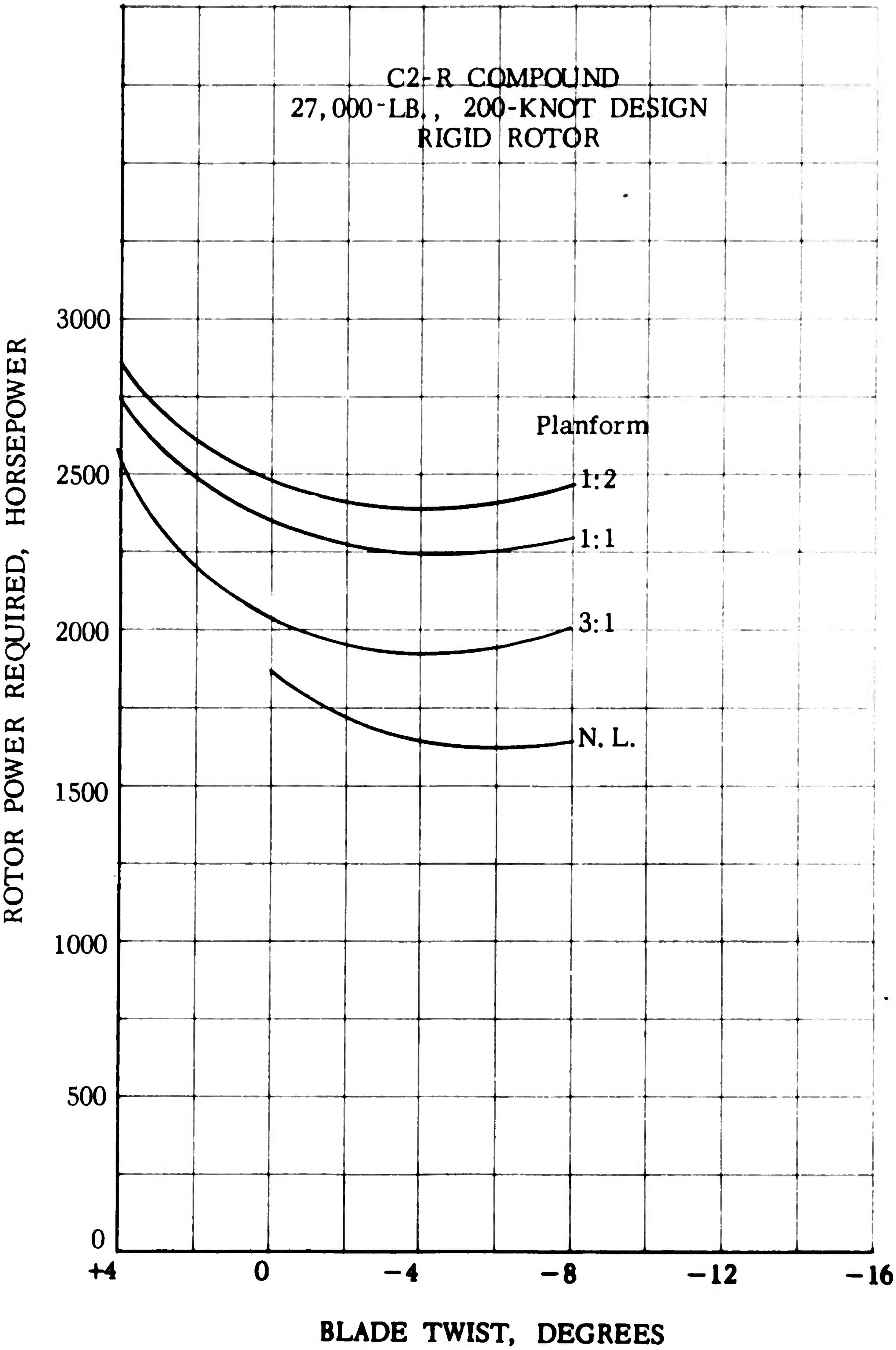


FIG. 7.16 CHANGE IN POWER WITH BLADE TWIST

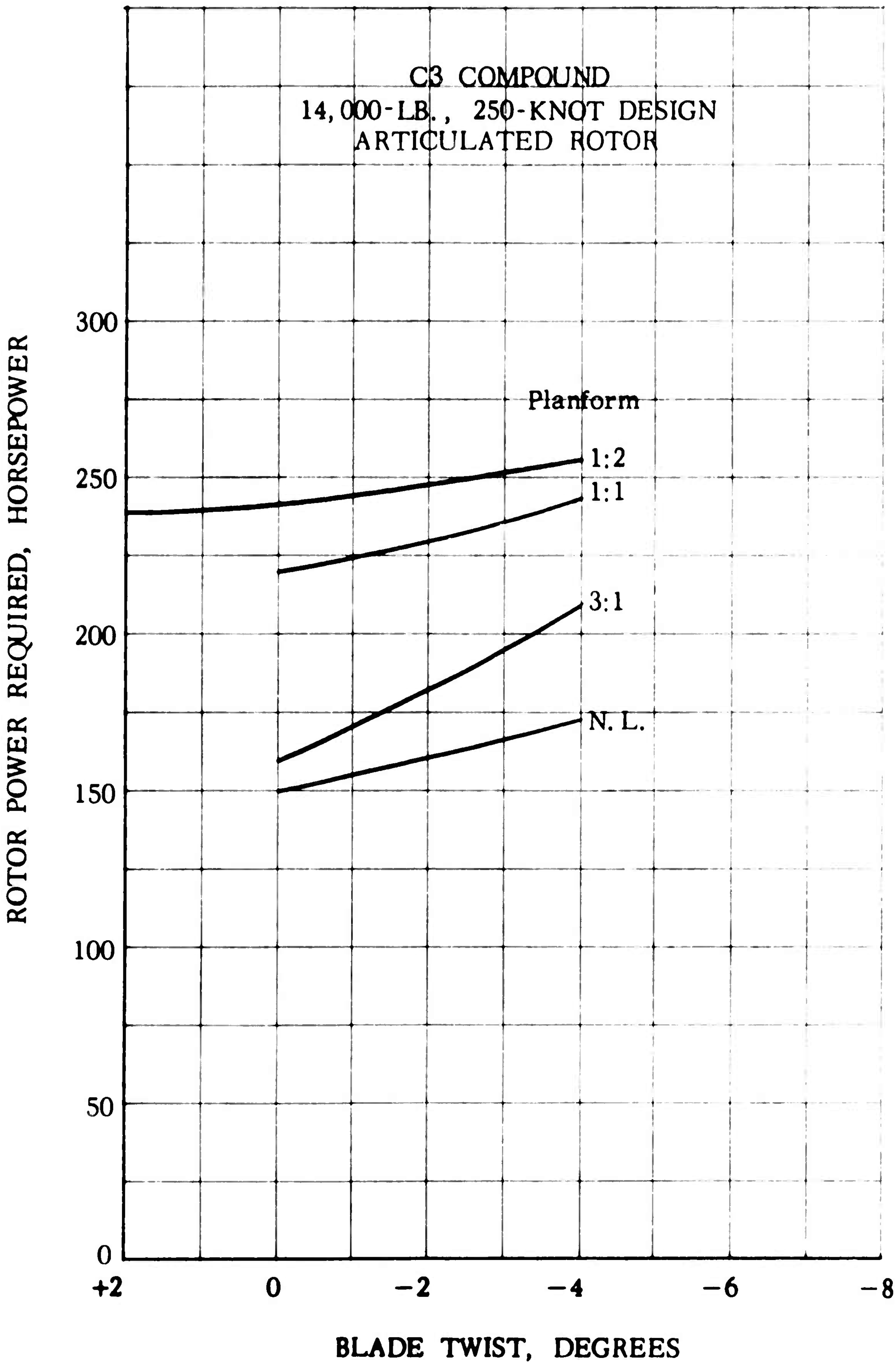


FIG. 7.17 CHANGE IN POWER WITH BLADE TWIST

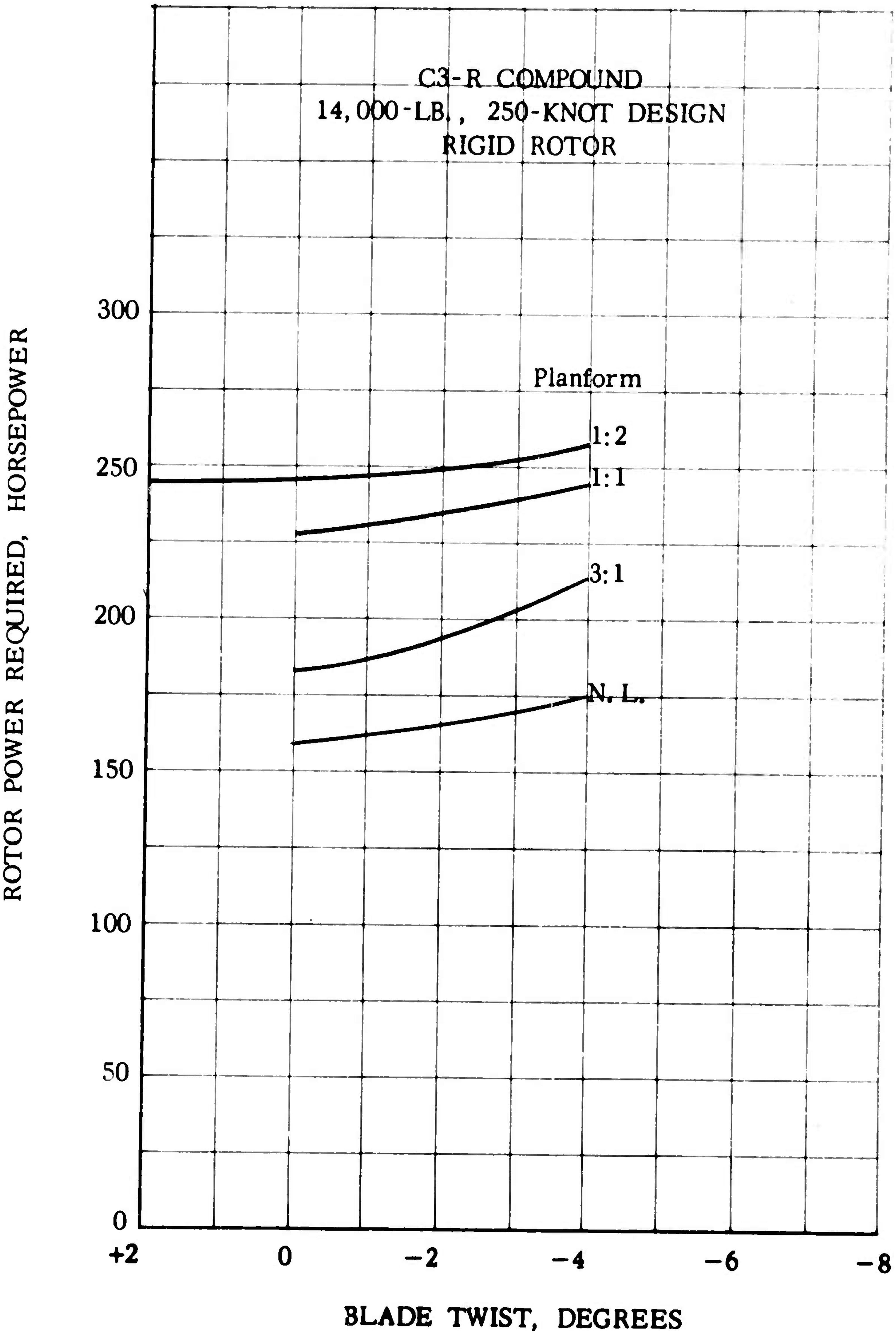


FIG. 7.18 CHANGE IN POWER WITH BLADE TWIST

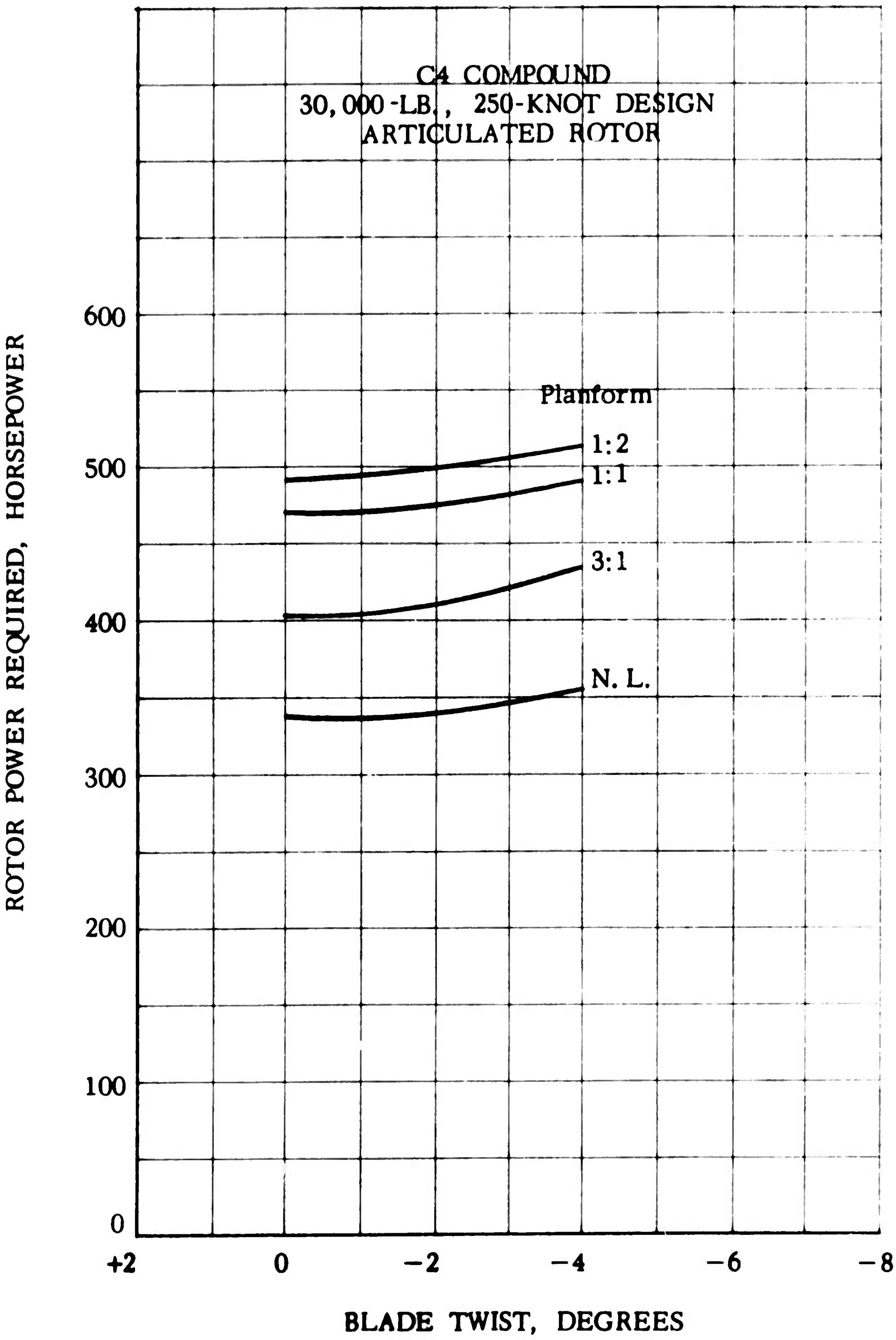


FIG. 7.19 CHANGE IN POWER WITH BLADE TWIST

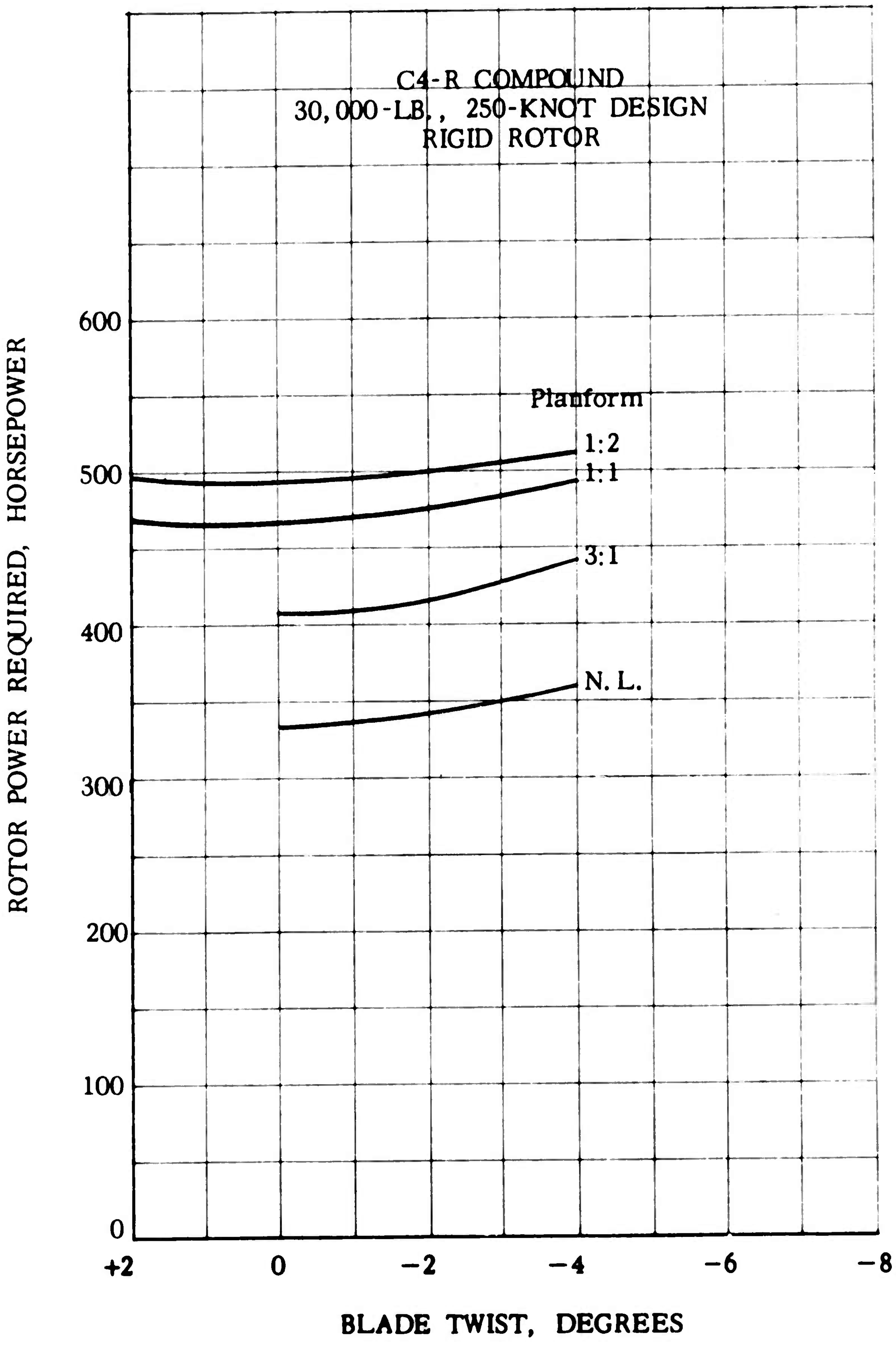


FIG. 7.20 CHANGE IN POWER WITH BLADE TWIST

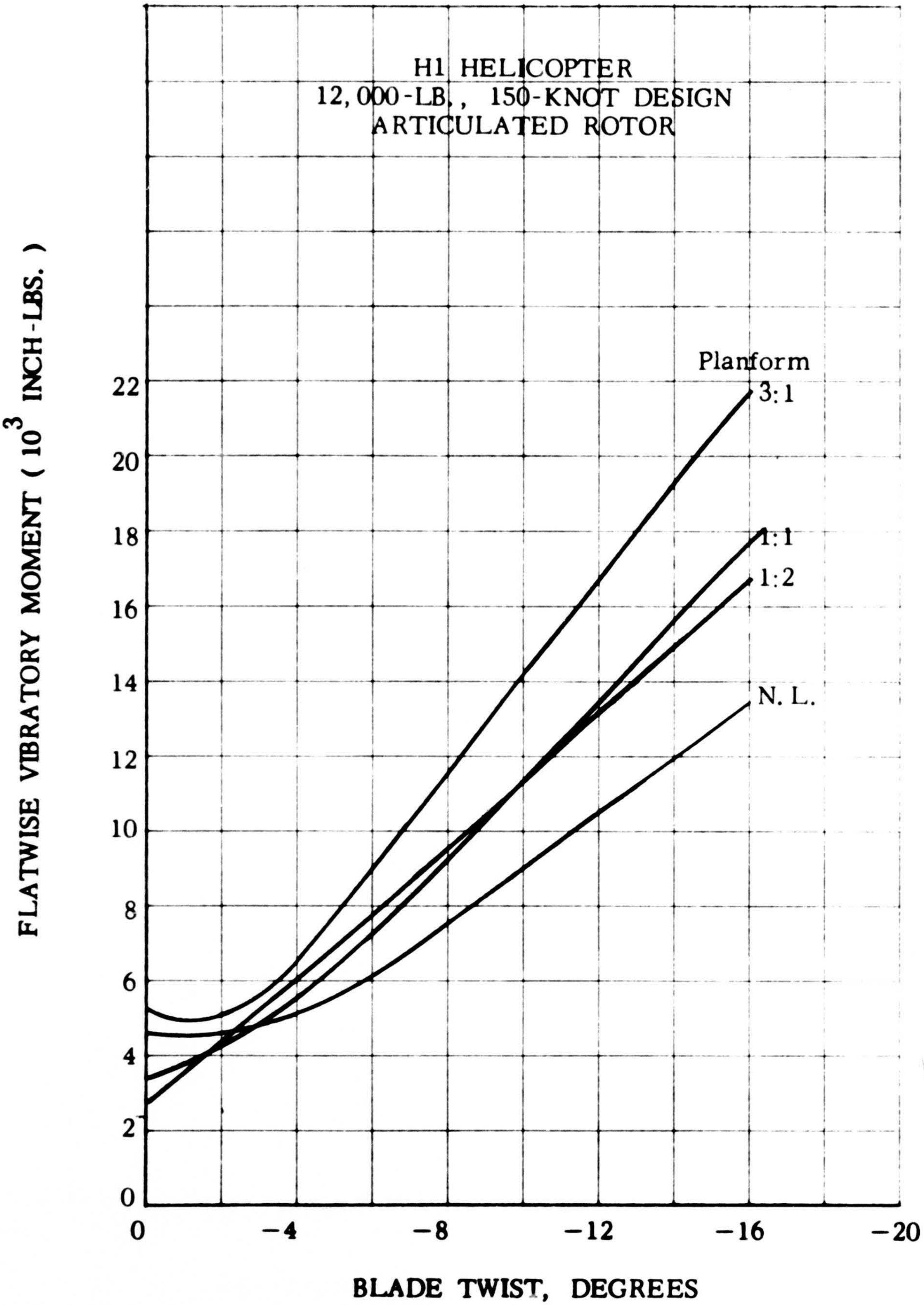


FIG. 7.21 EFFECT OF TWIST ON FLATWISE MOMENT

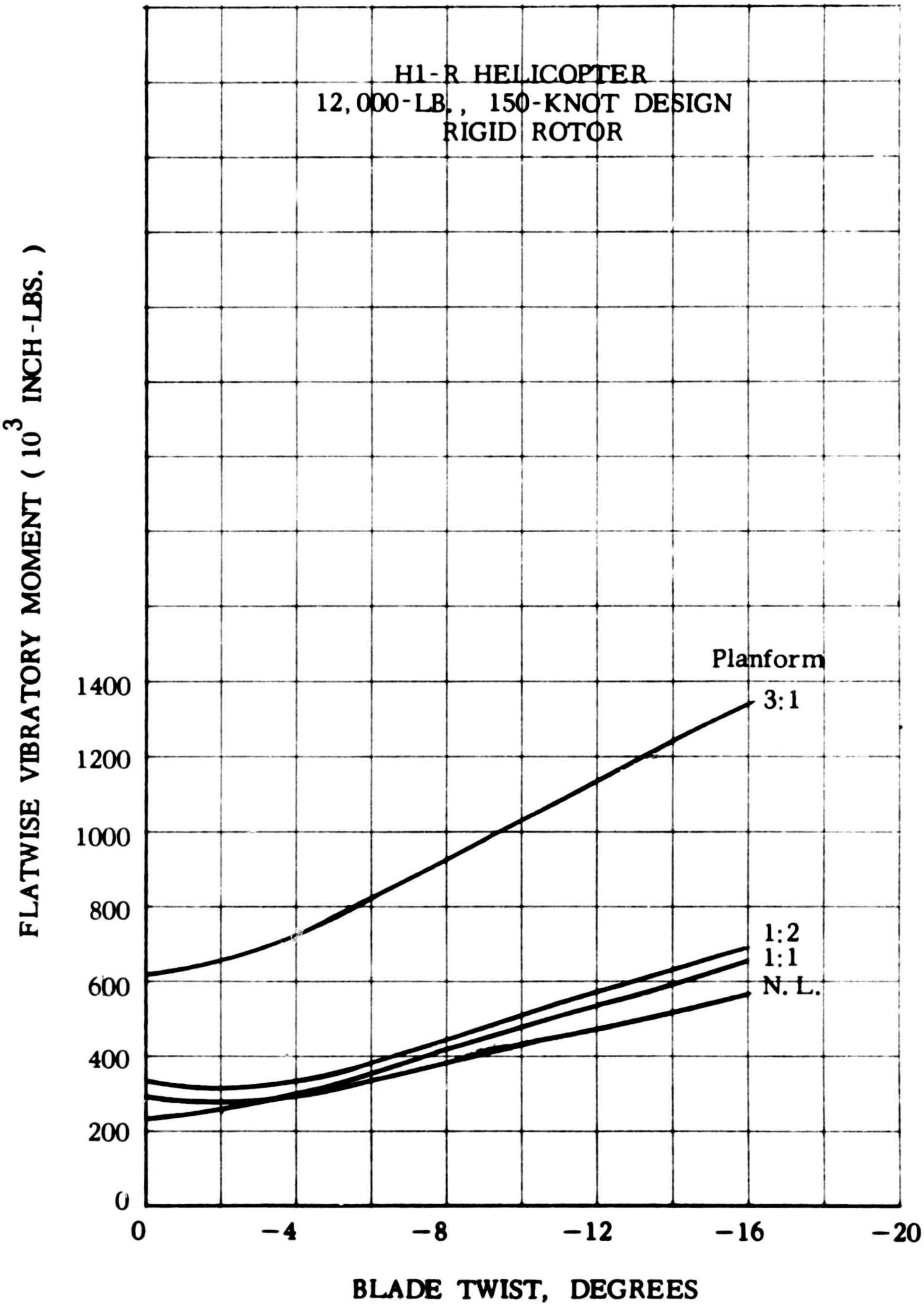


FIG. 7.22 EFFECT OF TWIST ON FLATWISE MOMENT

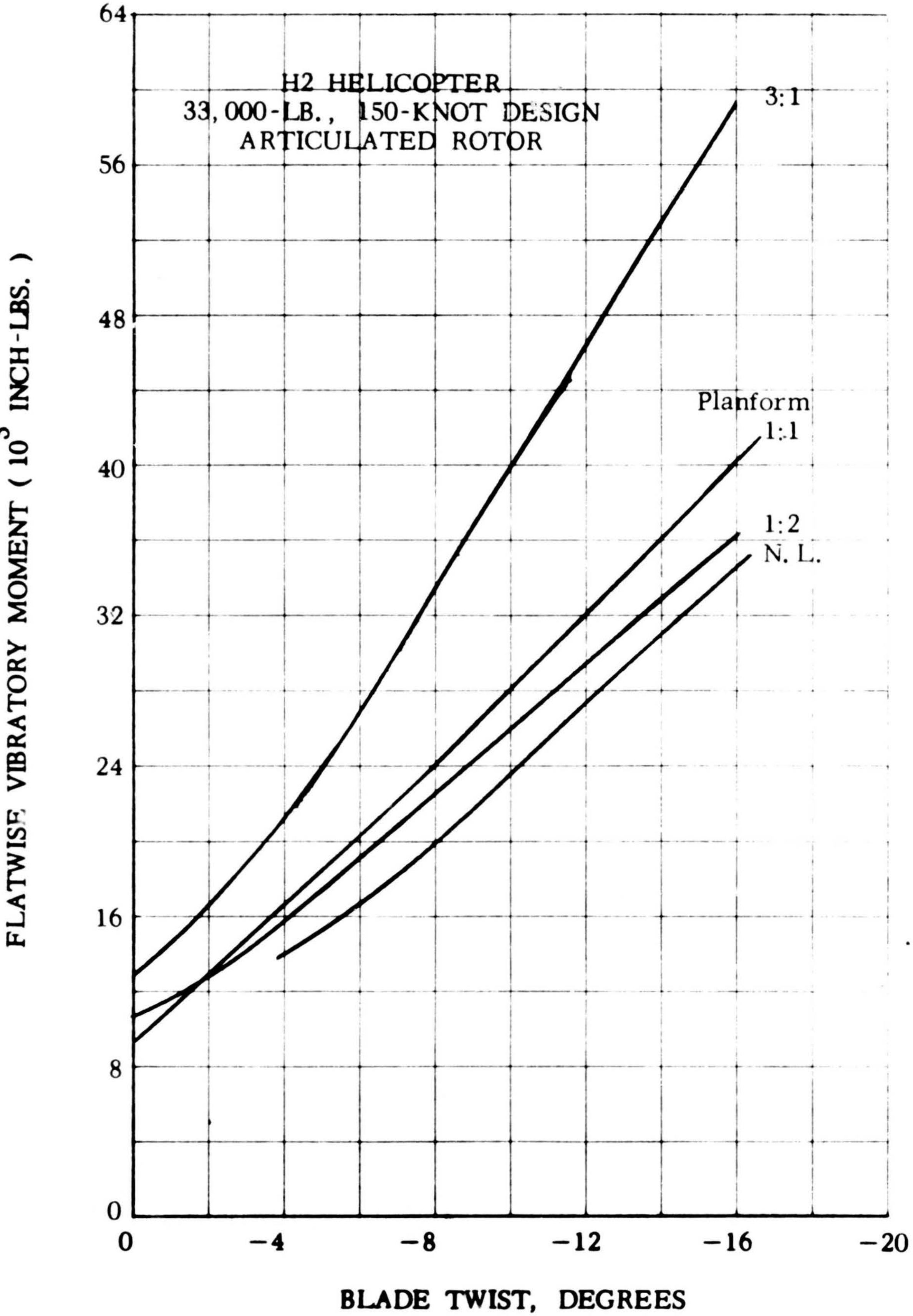


FIG. 7.23 EFFECT OF TWIST ON FLATWISE MOMENT

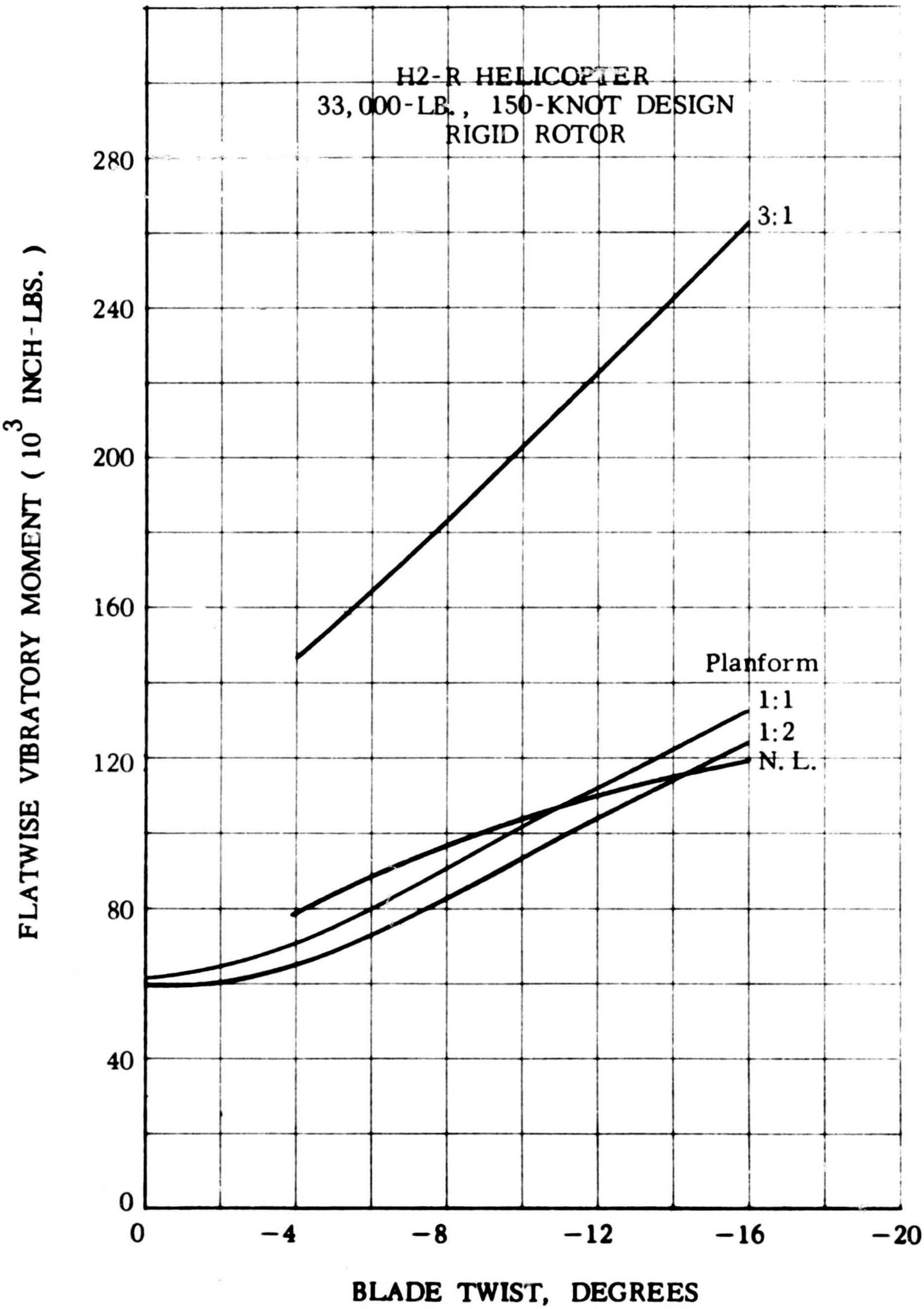


FIG. 7.24 EFFECT OF TWIST ON FLATWISE MOMENT

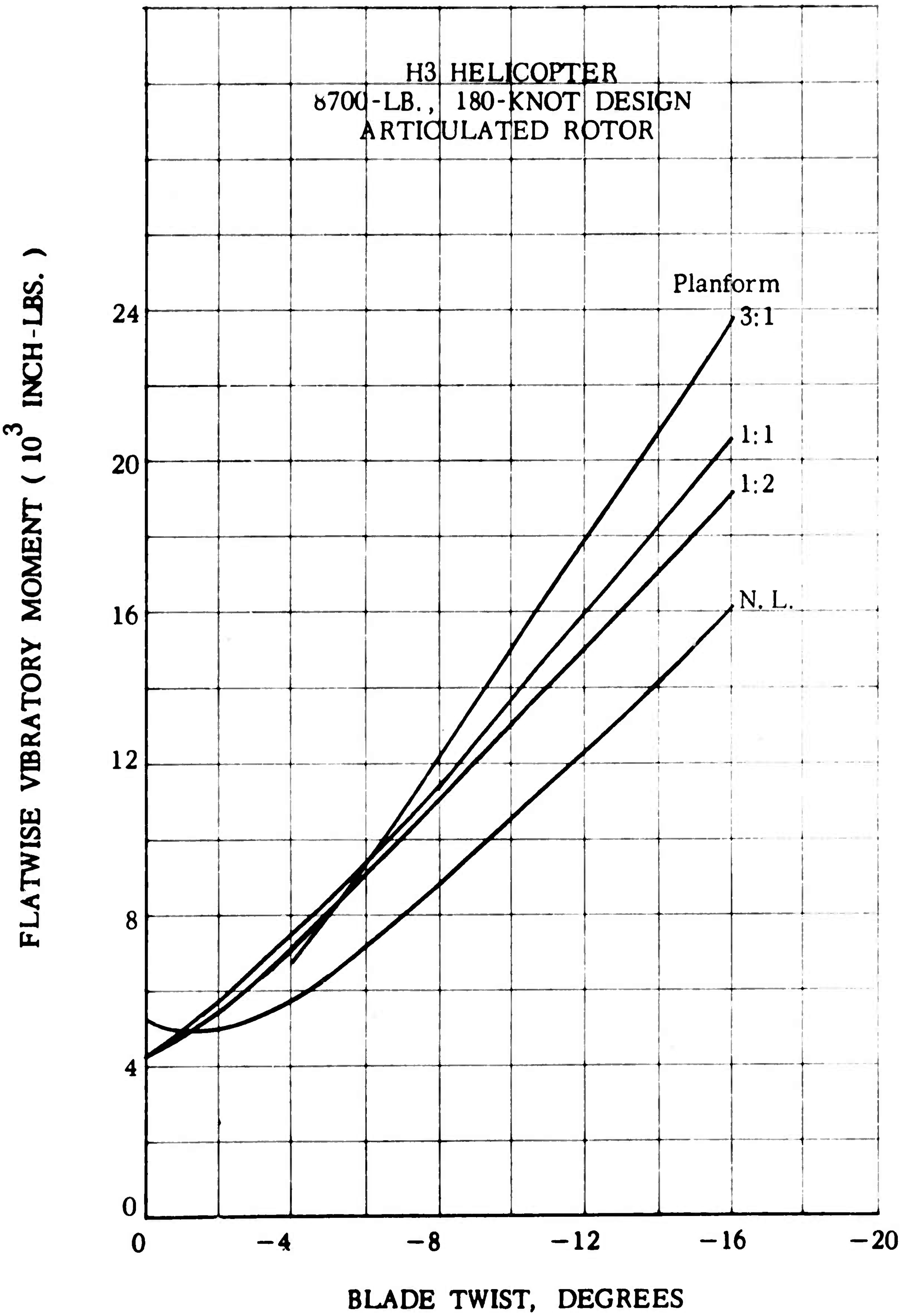


FIG. 7.25 EFFECT OF TWIST ON FLATWISE MOMENT

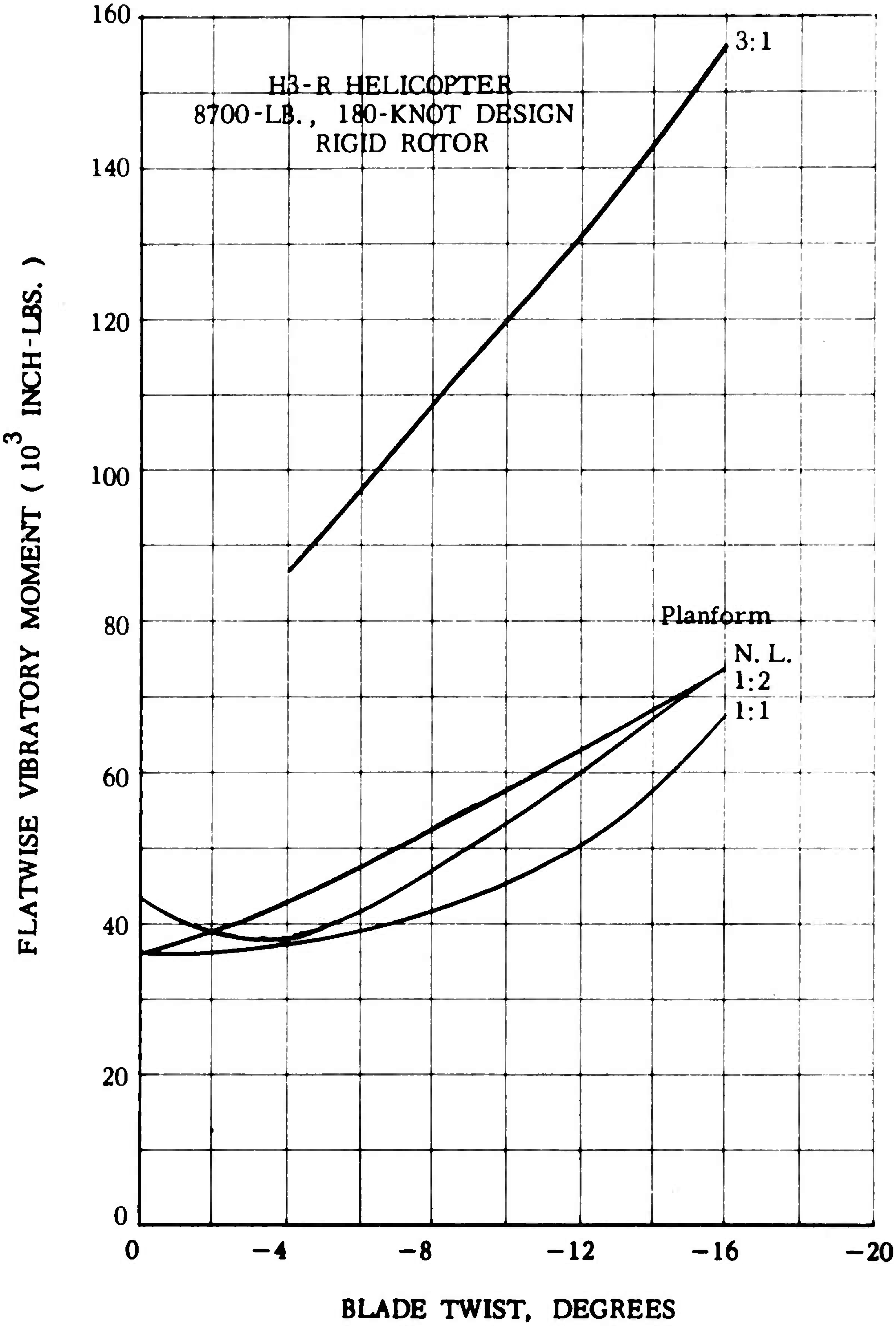


FIG. 7.26 EFFECT OF TWIST ON FLATWISE MOMENT

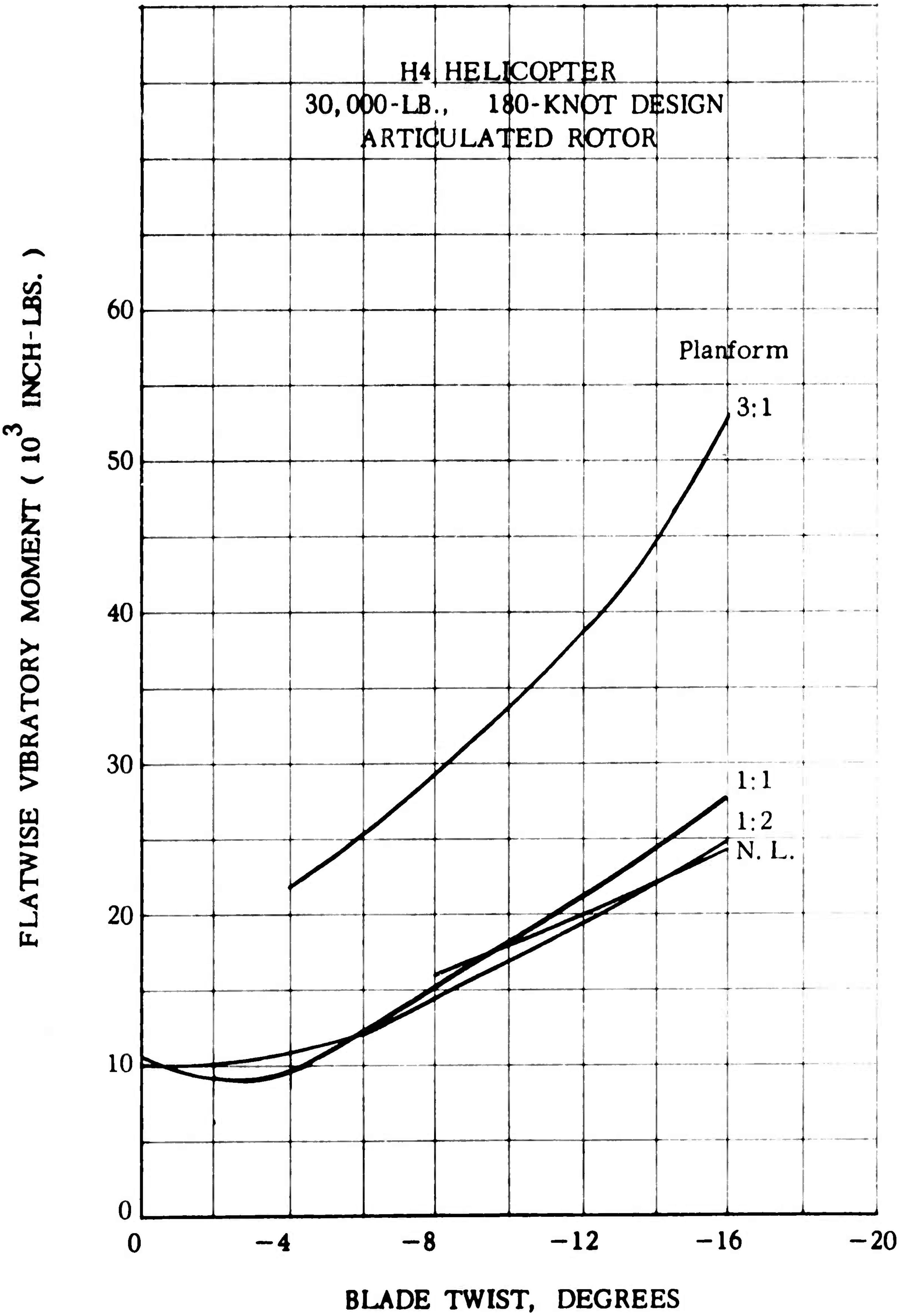


FIG. 7.27 EFFECT OF TWIST ON FLATWISE MOMENT

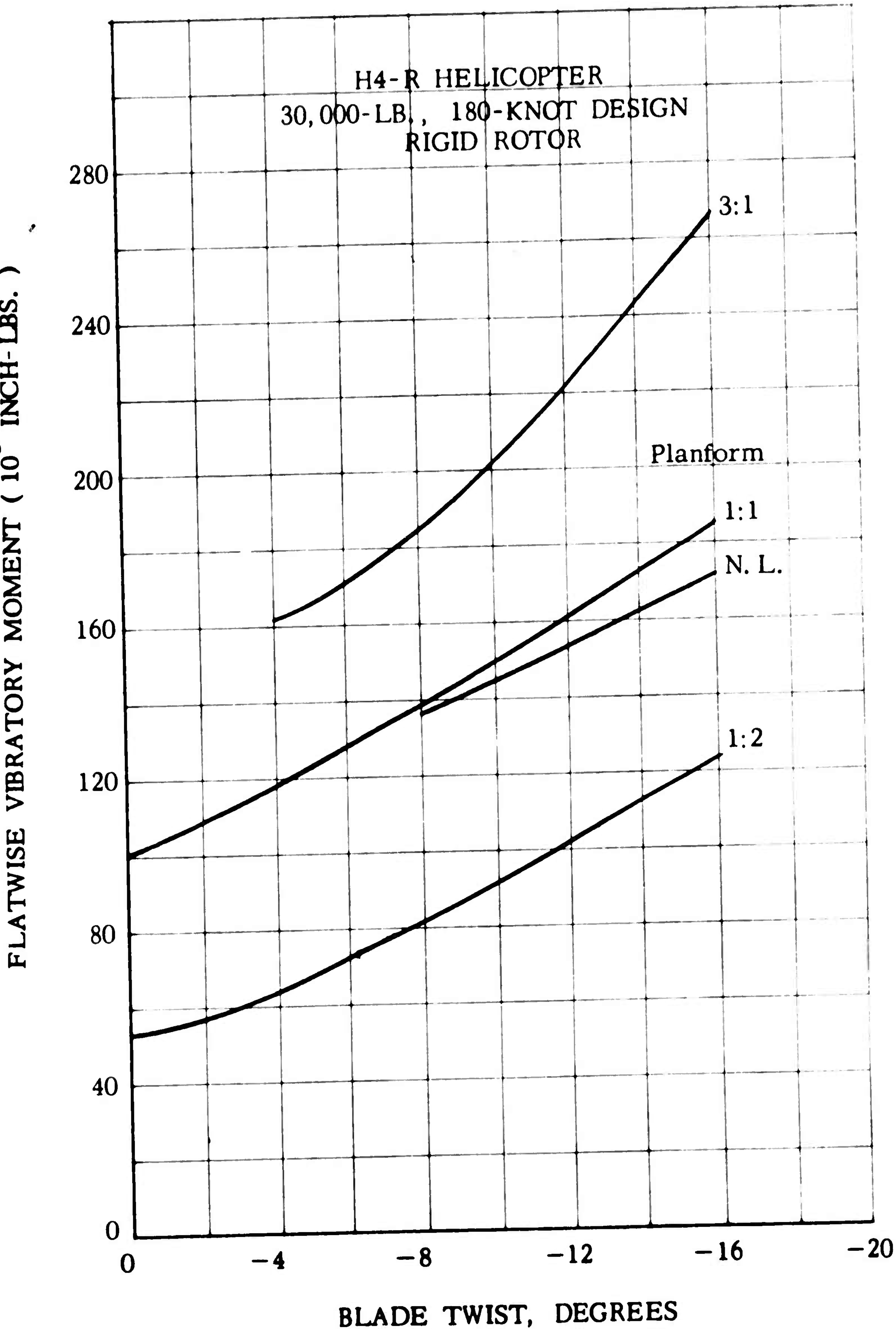


FIG. 7.28 EFFECT OF TWIST ON FLATWISE MOMENT

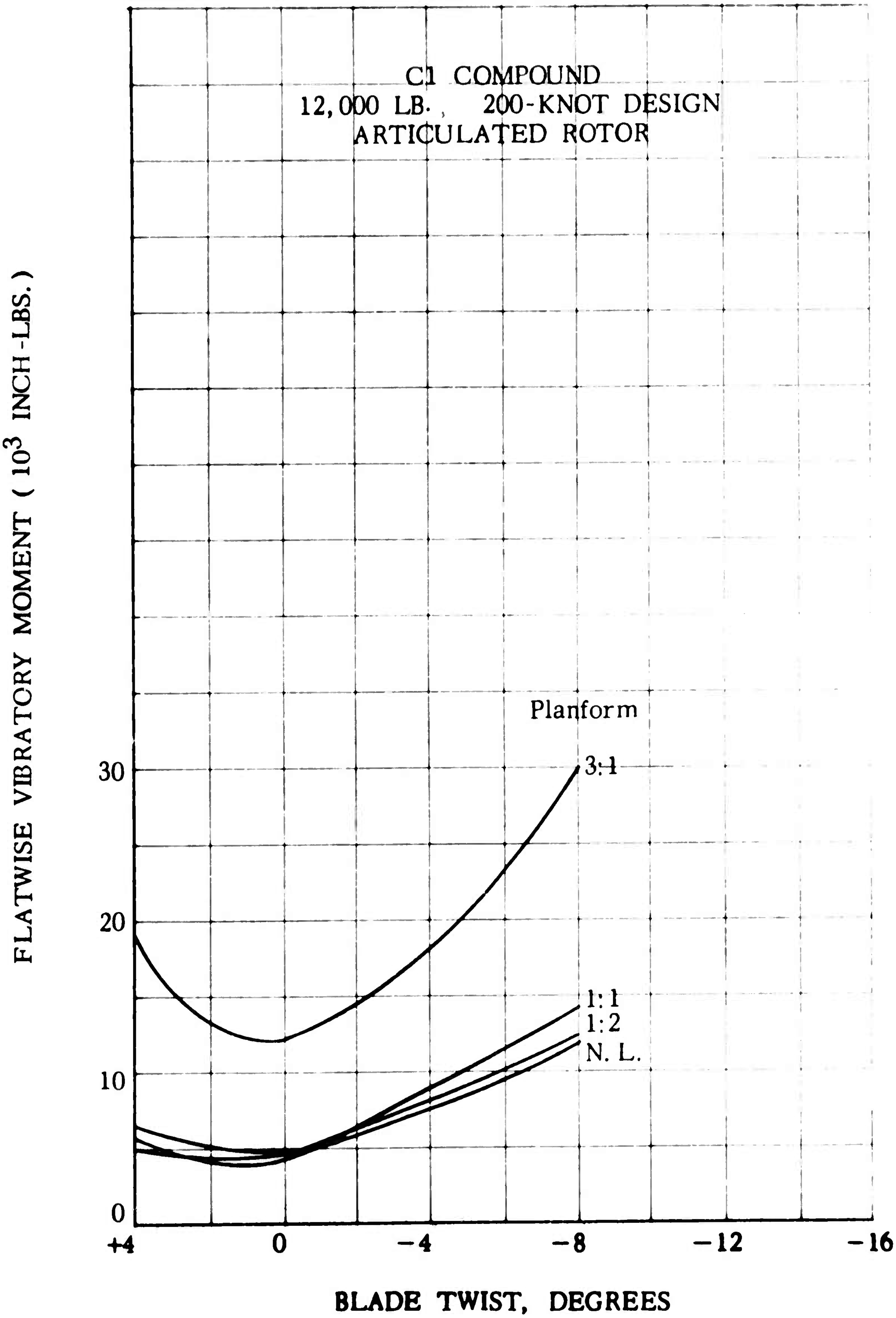


FIG. 7.29 EFFECT OF TWIST ON FLATWISE MOMENT

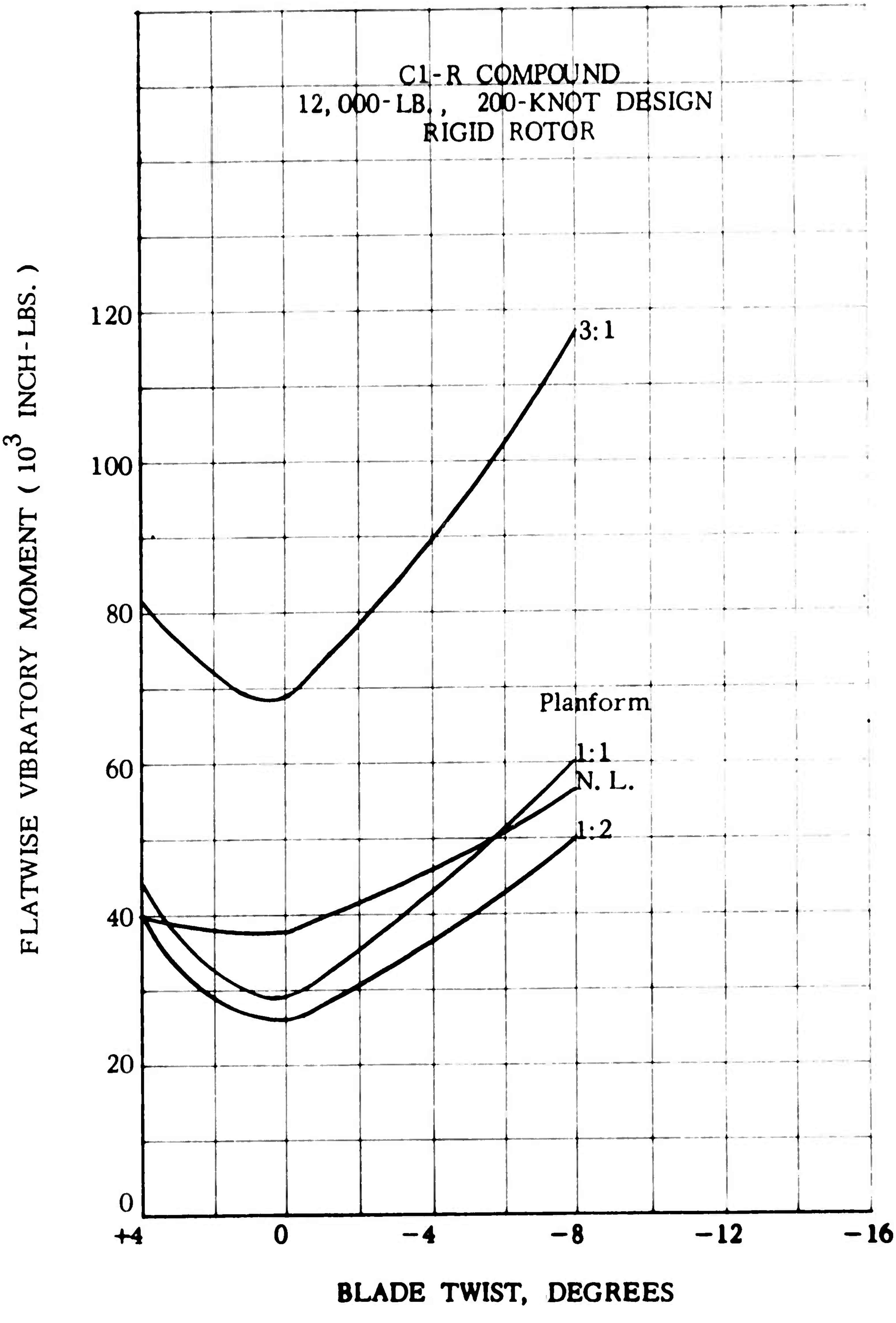


FIG. 7.30 EFFECT OF TWIST ON FLATWISE MOMENT

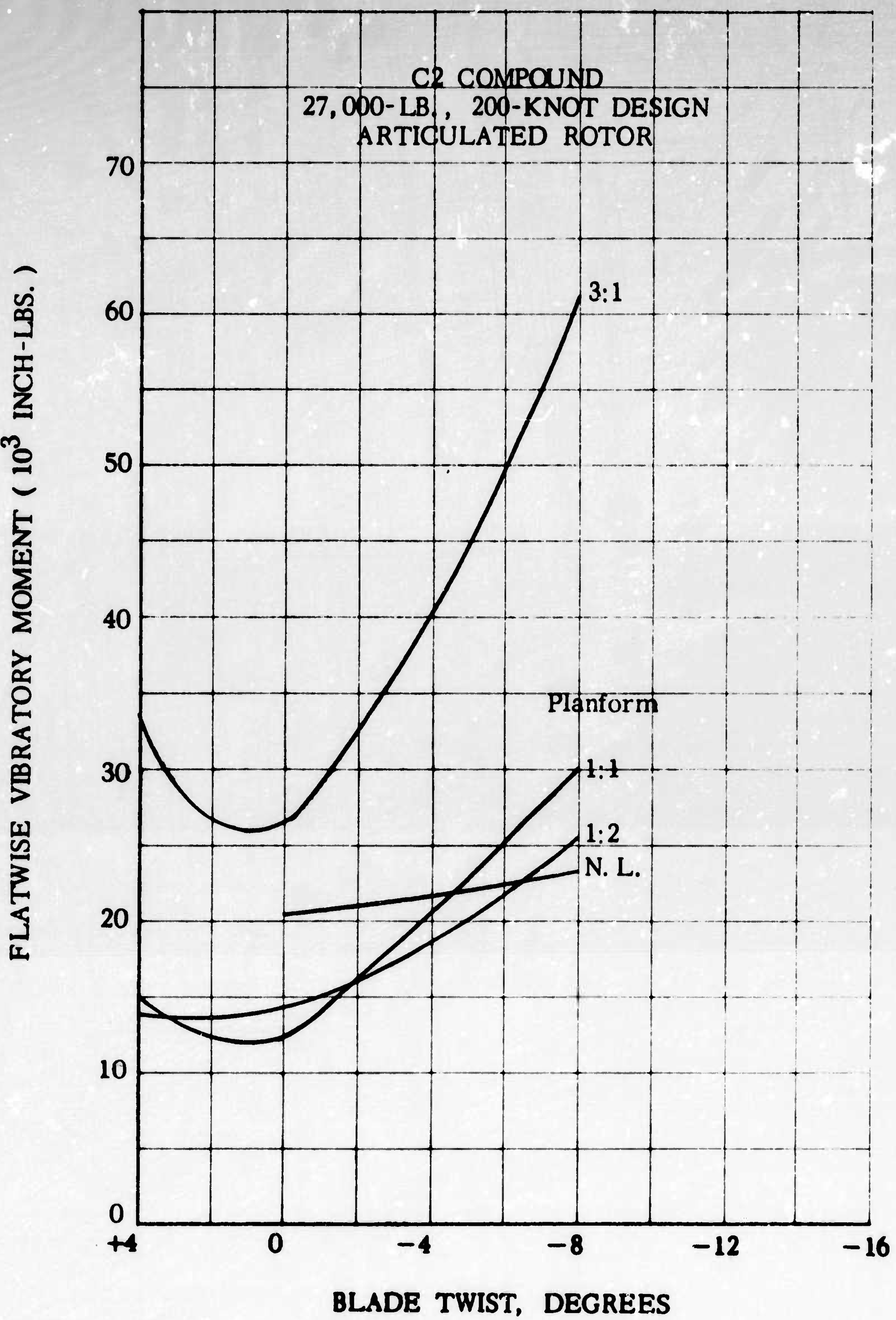


FIG.7.31 EFFECT OF TWIST ON FLATWISE MOMENT

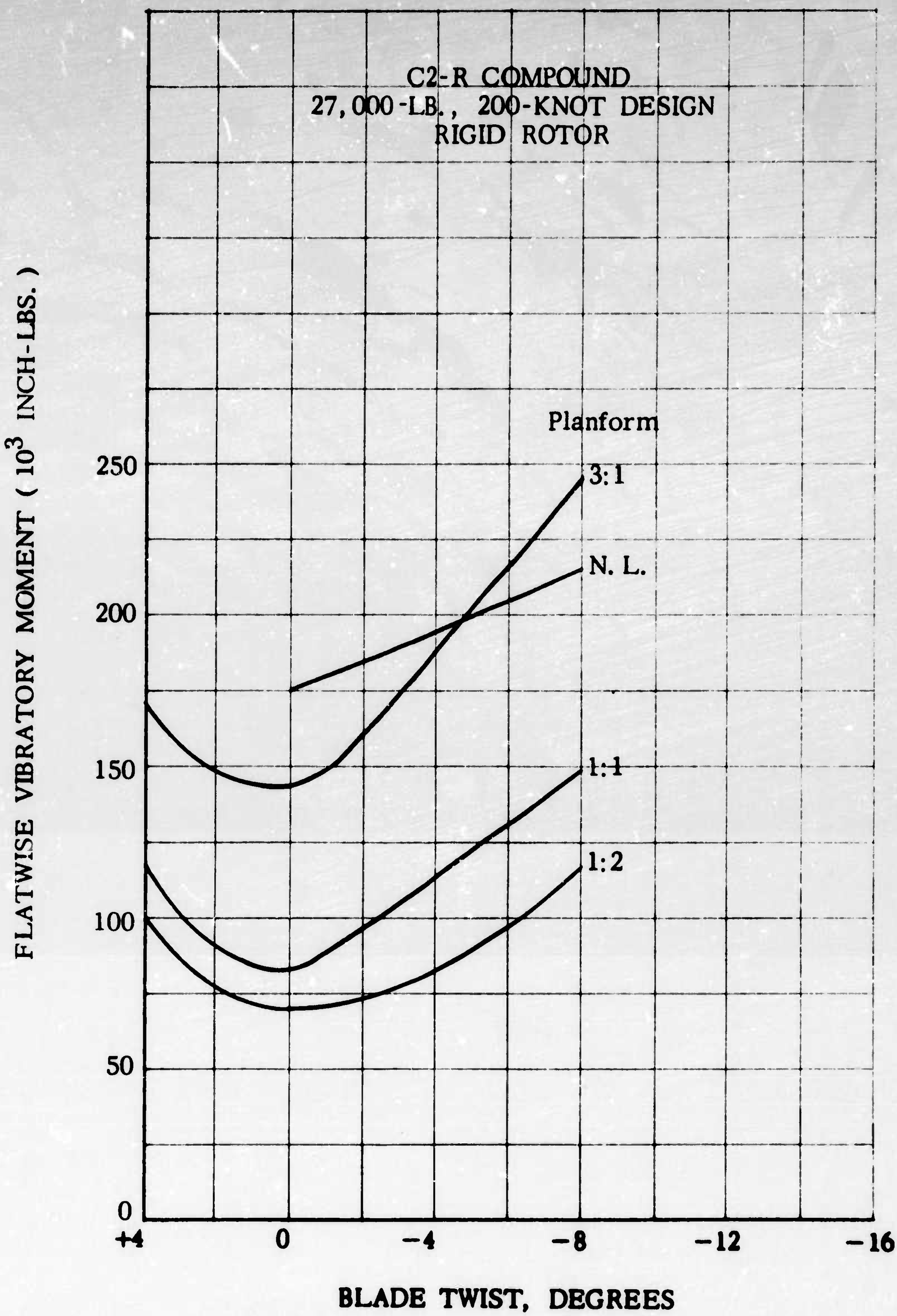


FIG. 7.32 EFFECT OF TWIST ON FLATWISE MOMENT

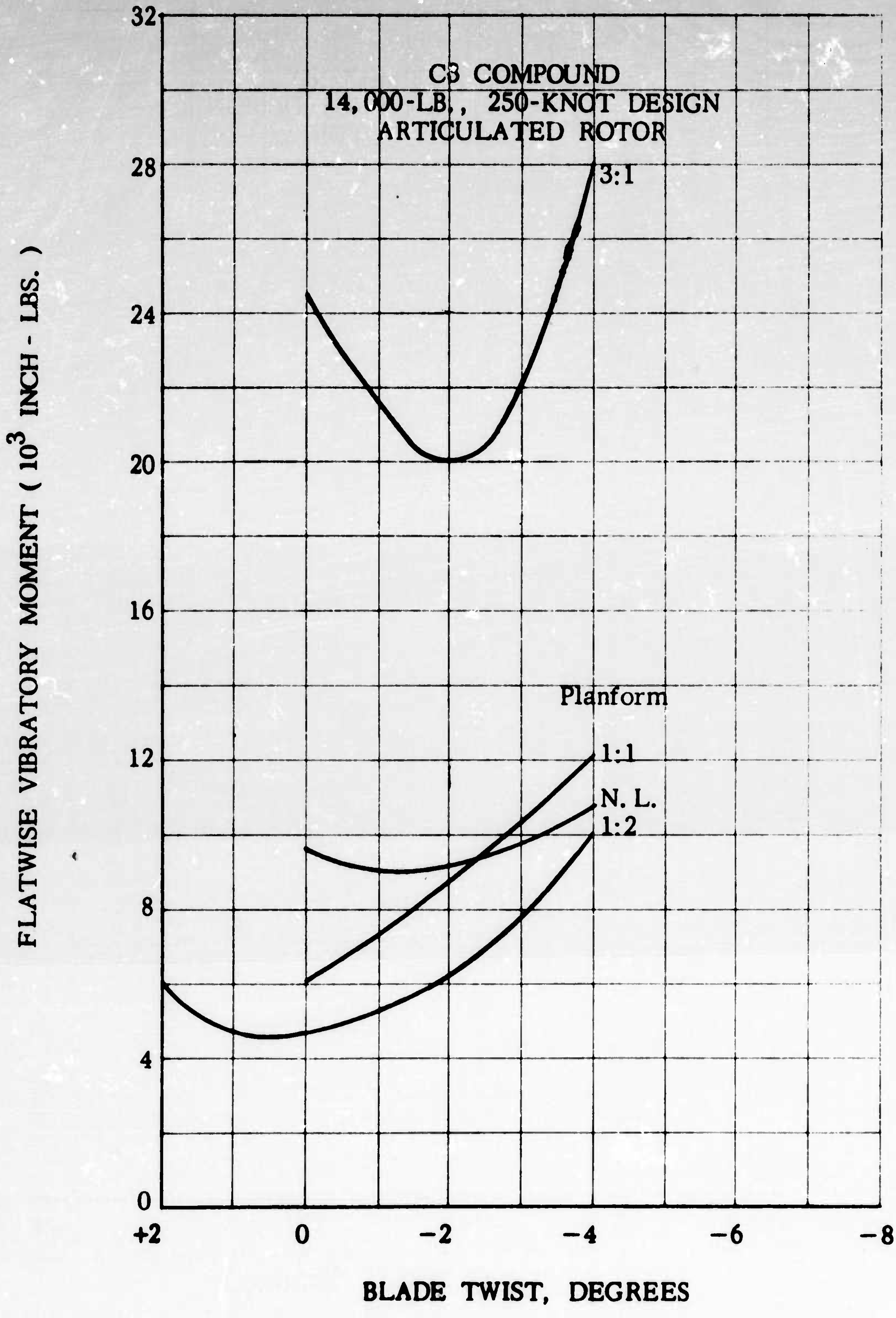


FIG. 7.33 EFFECT OF TWIST ON FLATWISE MOMENT

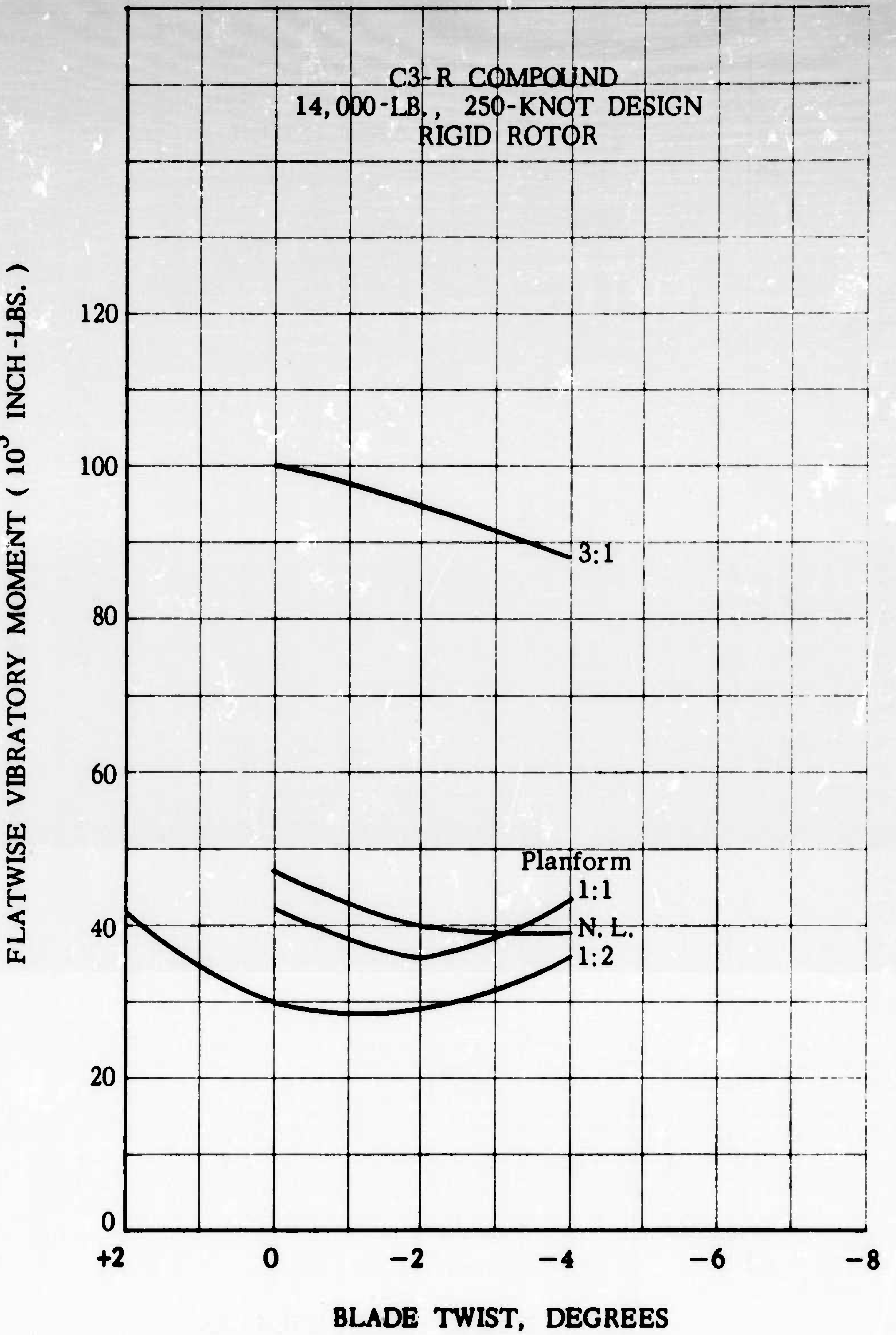


FIG. 7.34 EFFECT OF TWIST ON FLATWISE MOMENT

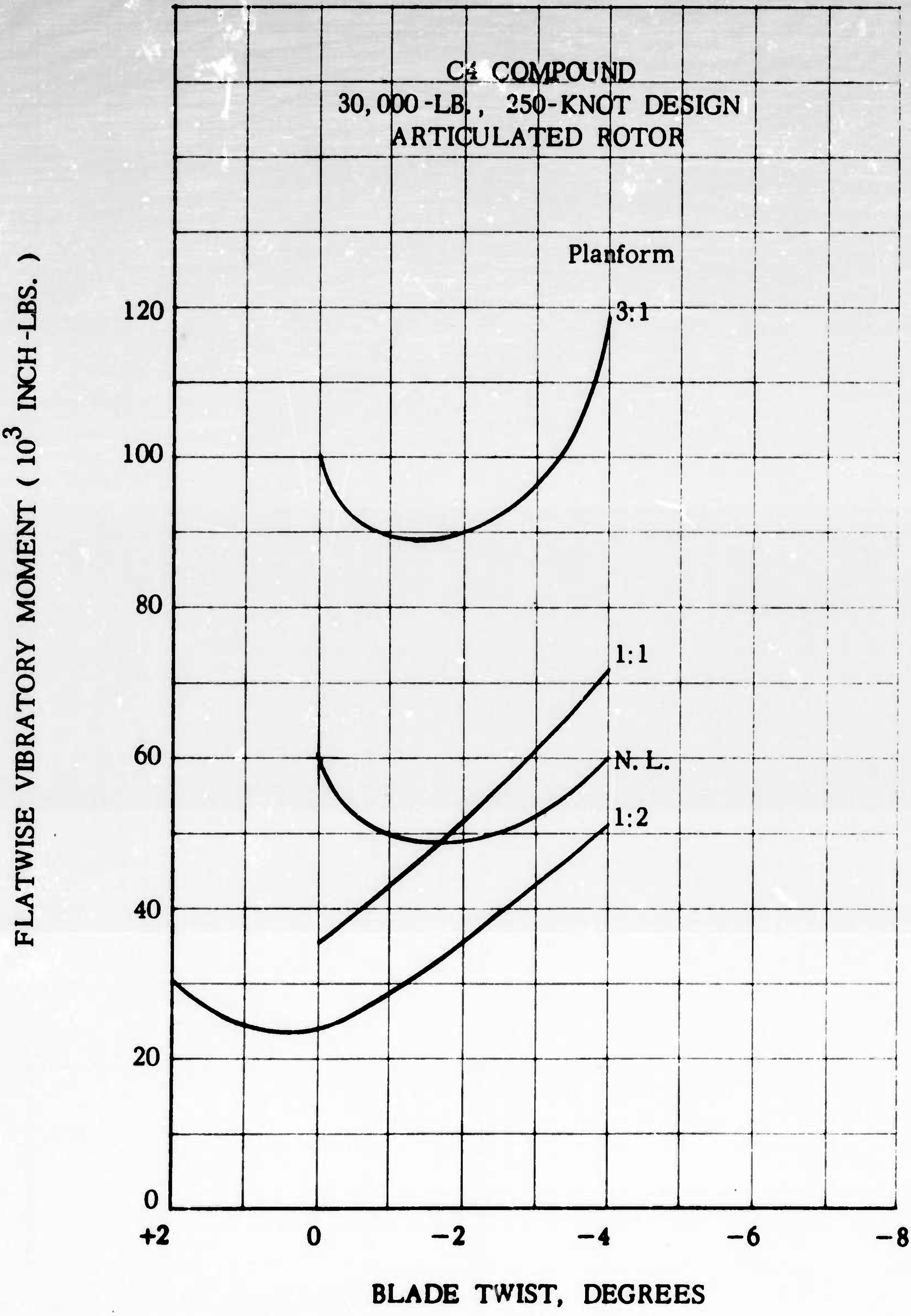


FIG. 7.35 EFFECT OF TWIST ON FLATWISE MOMENT

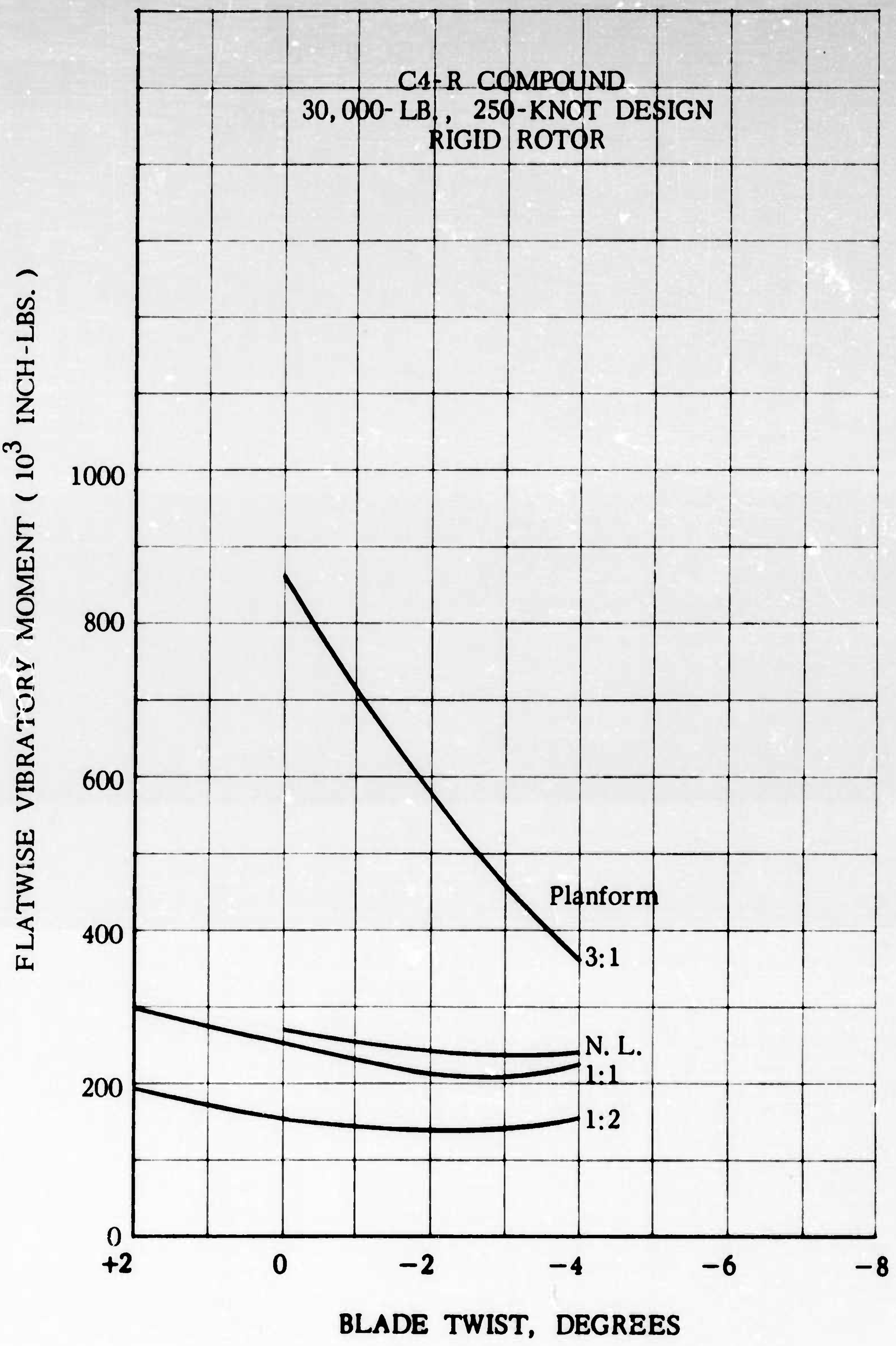


FIG. 7.36 EFFECT OF TWIST ON FLATWISE MOMENT

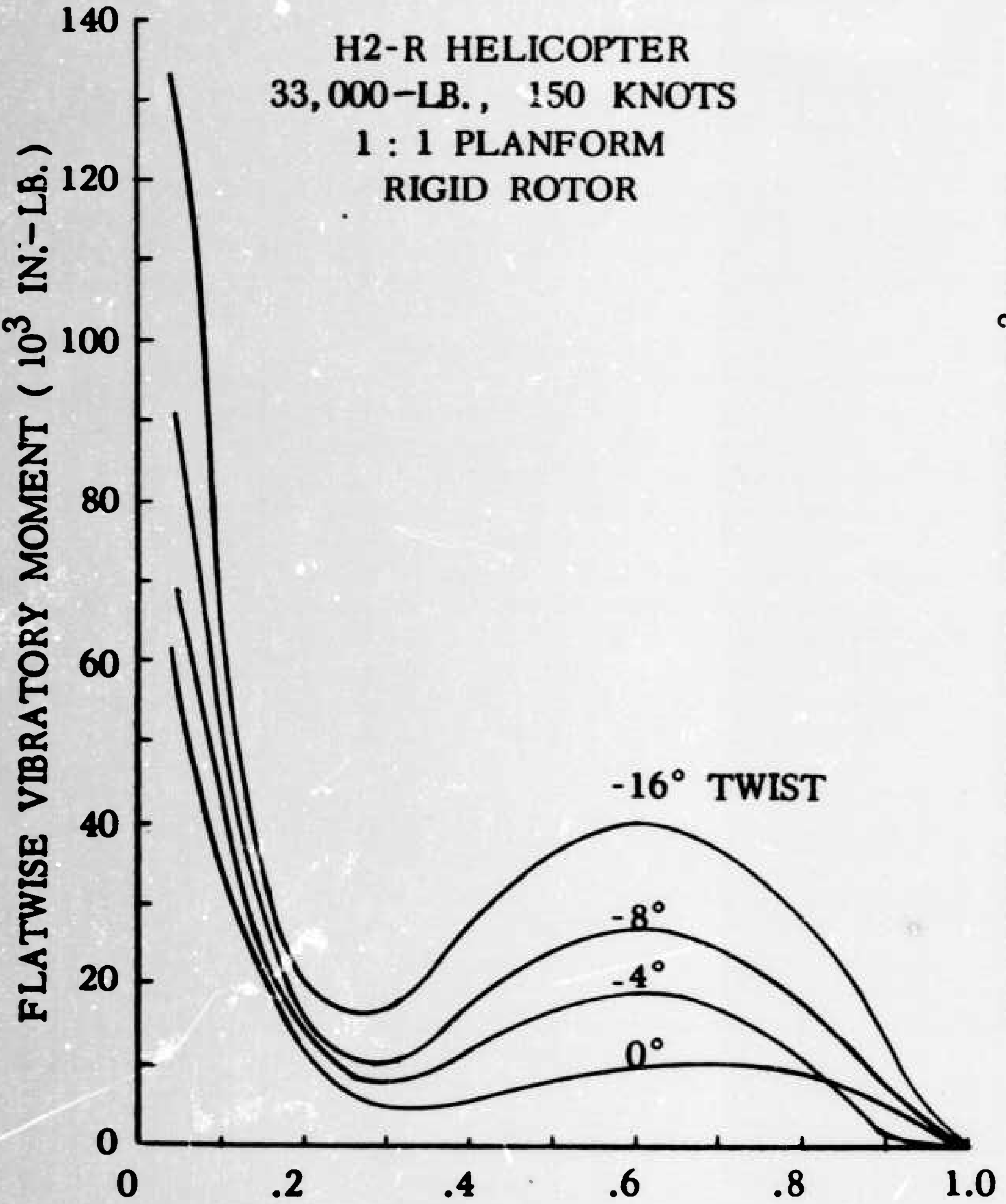


FIG. 7.38 BENDING MOMENT ENVELOPE

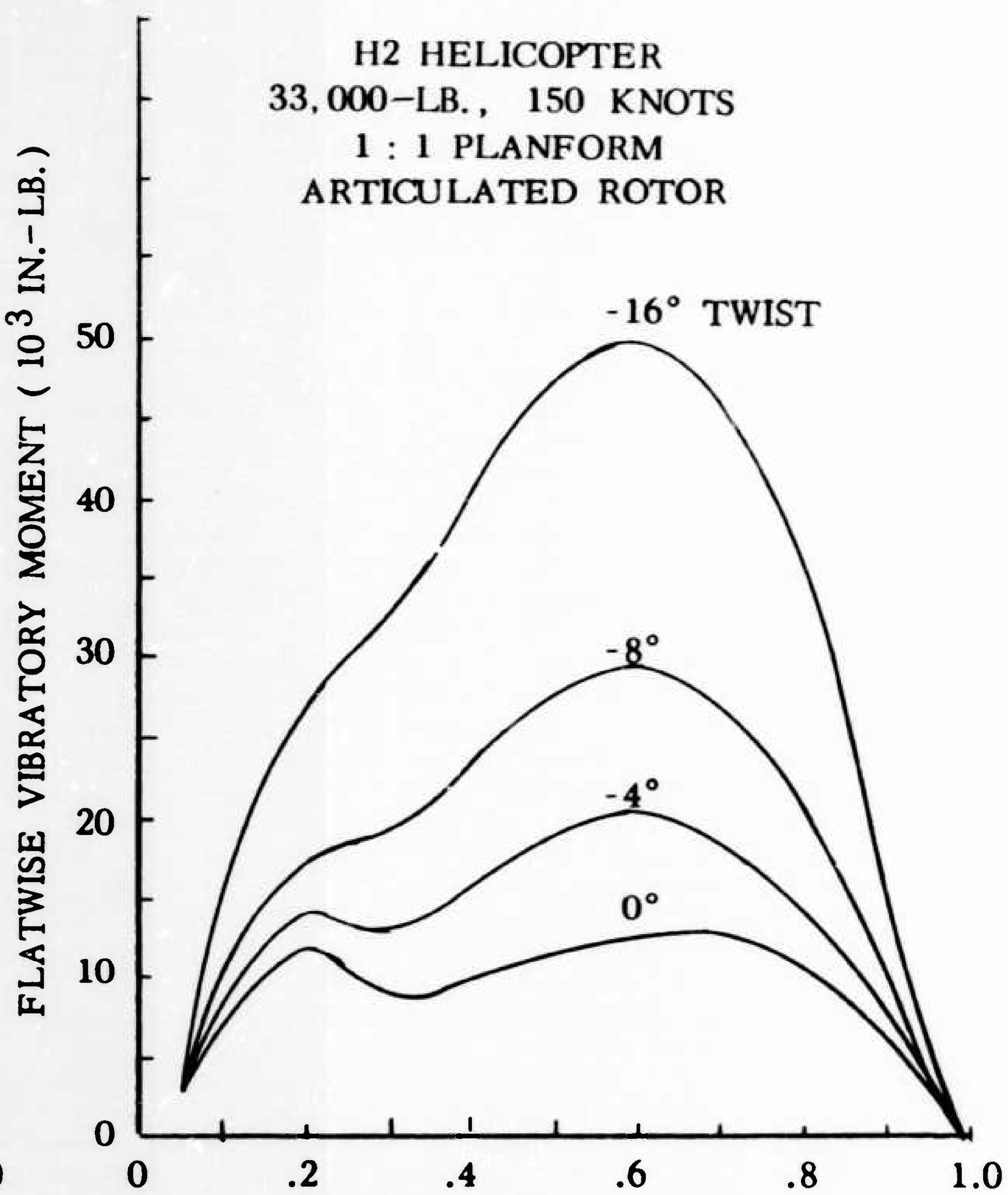


FIG. 7.39 BENDING MOMENT ENVELOPE

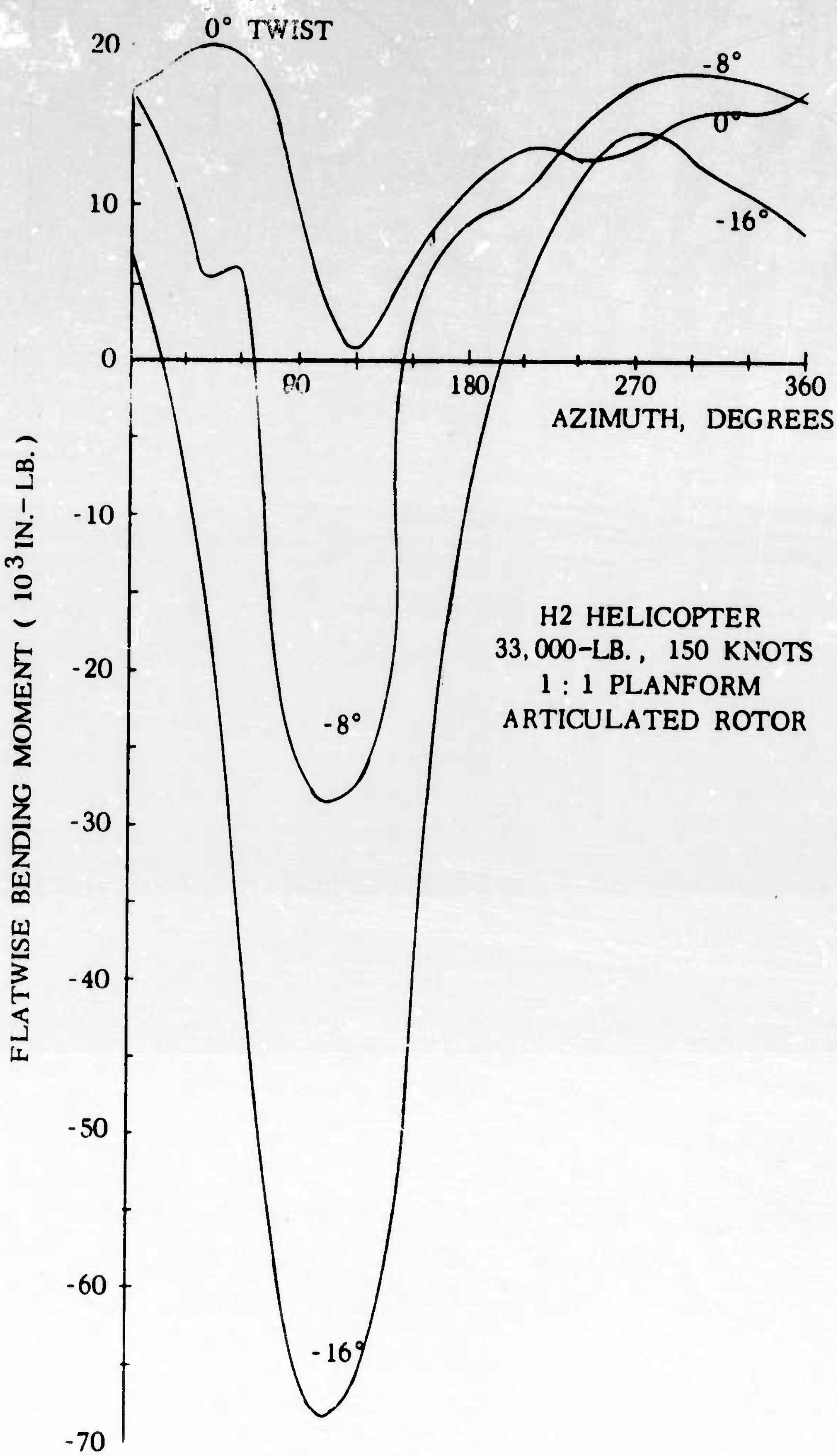


FIG. 7.40 CHANGE IN FLATWISE MOMENT WITH AZIMUTH FOR THREE VALUES OF TWIST

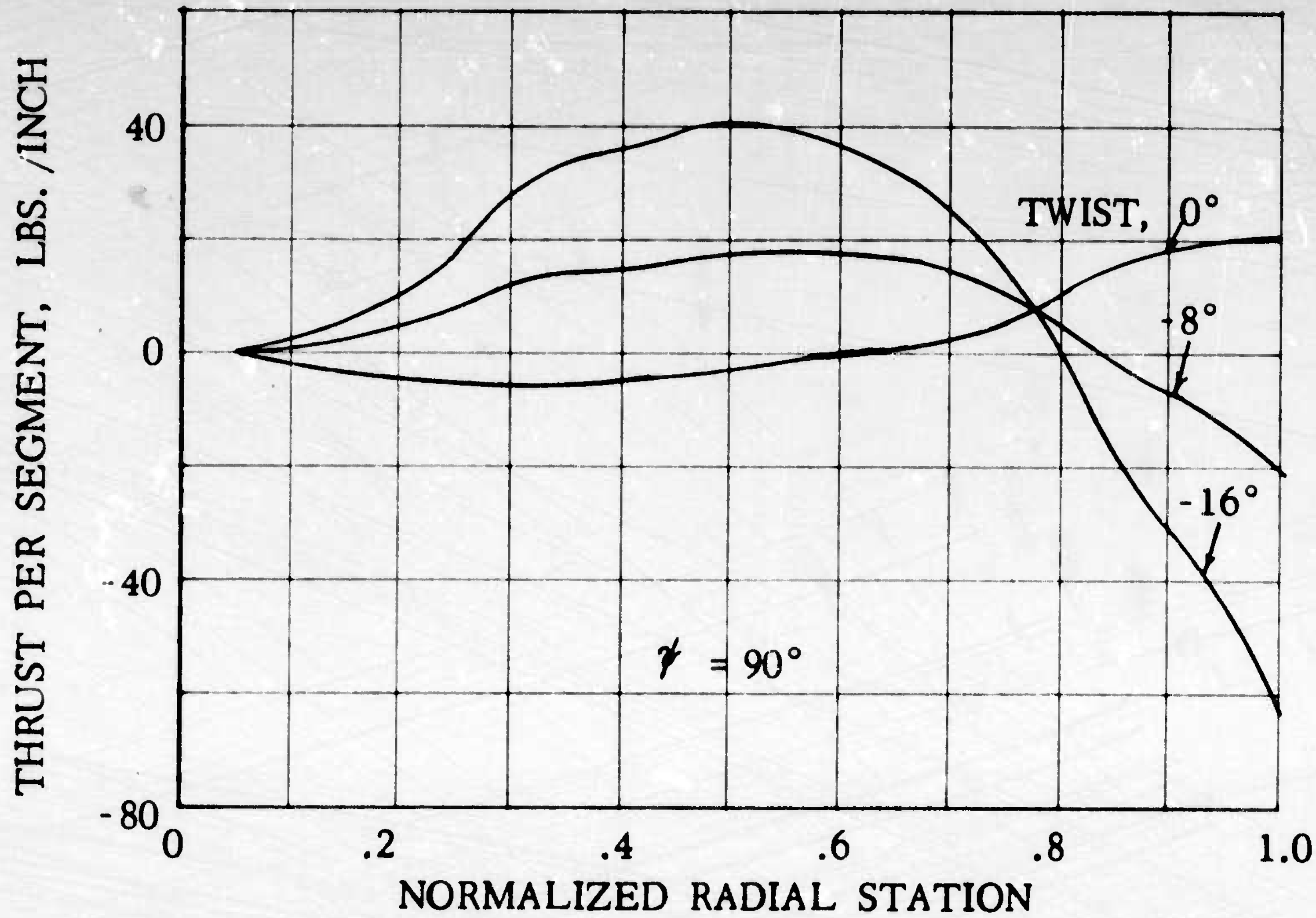


FIG. 7.41 CHANGE IN AIRLOAD DISTRIBUTION WITH TWIST

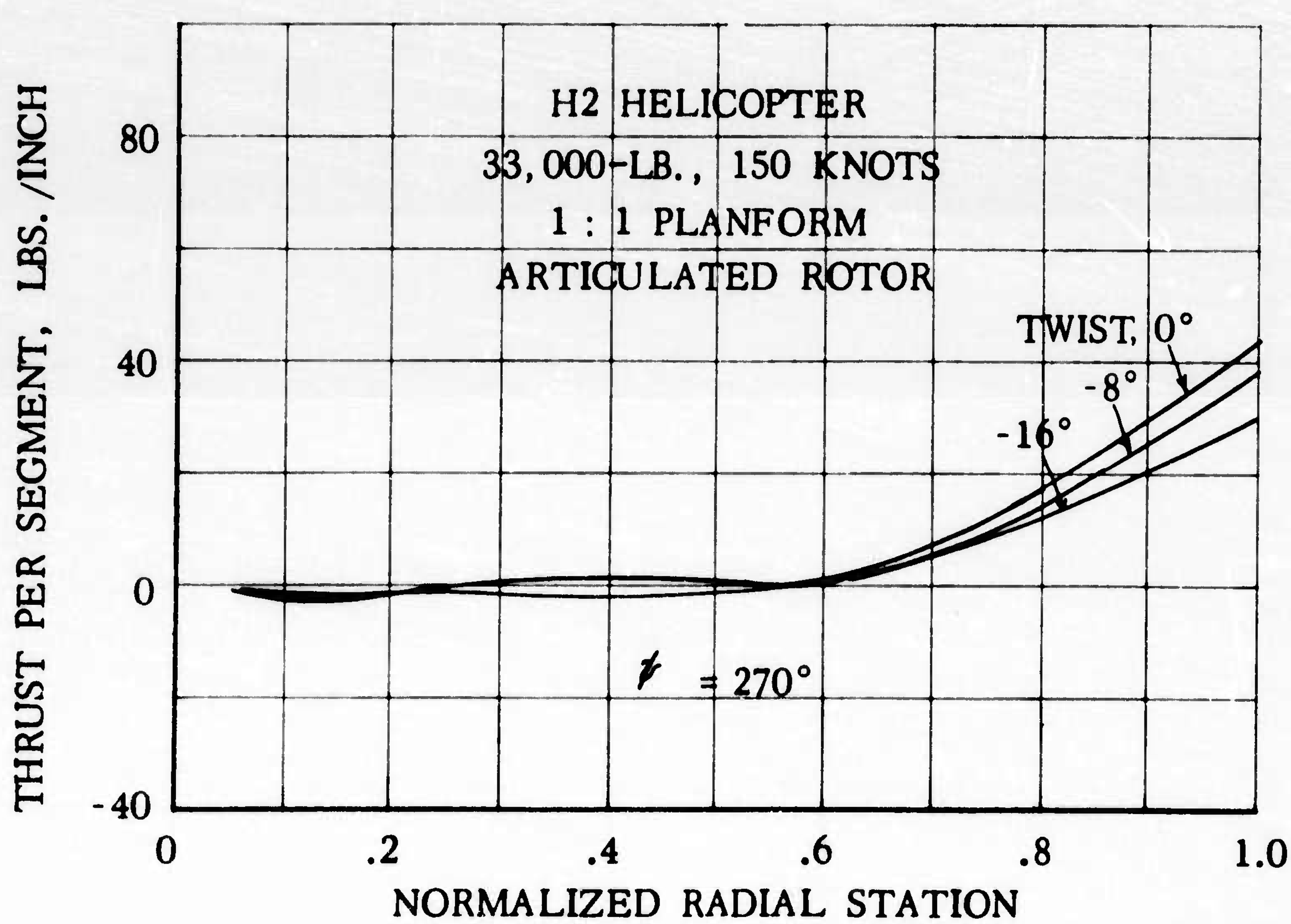


FIG. 7.42 CHANGE IN AIRLOAD DISTRIBUTION WITH TWIST

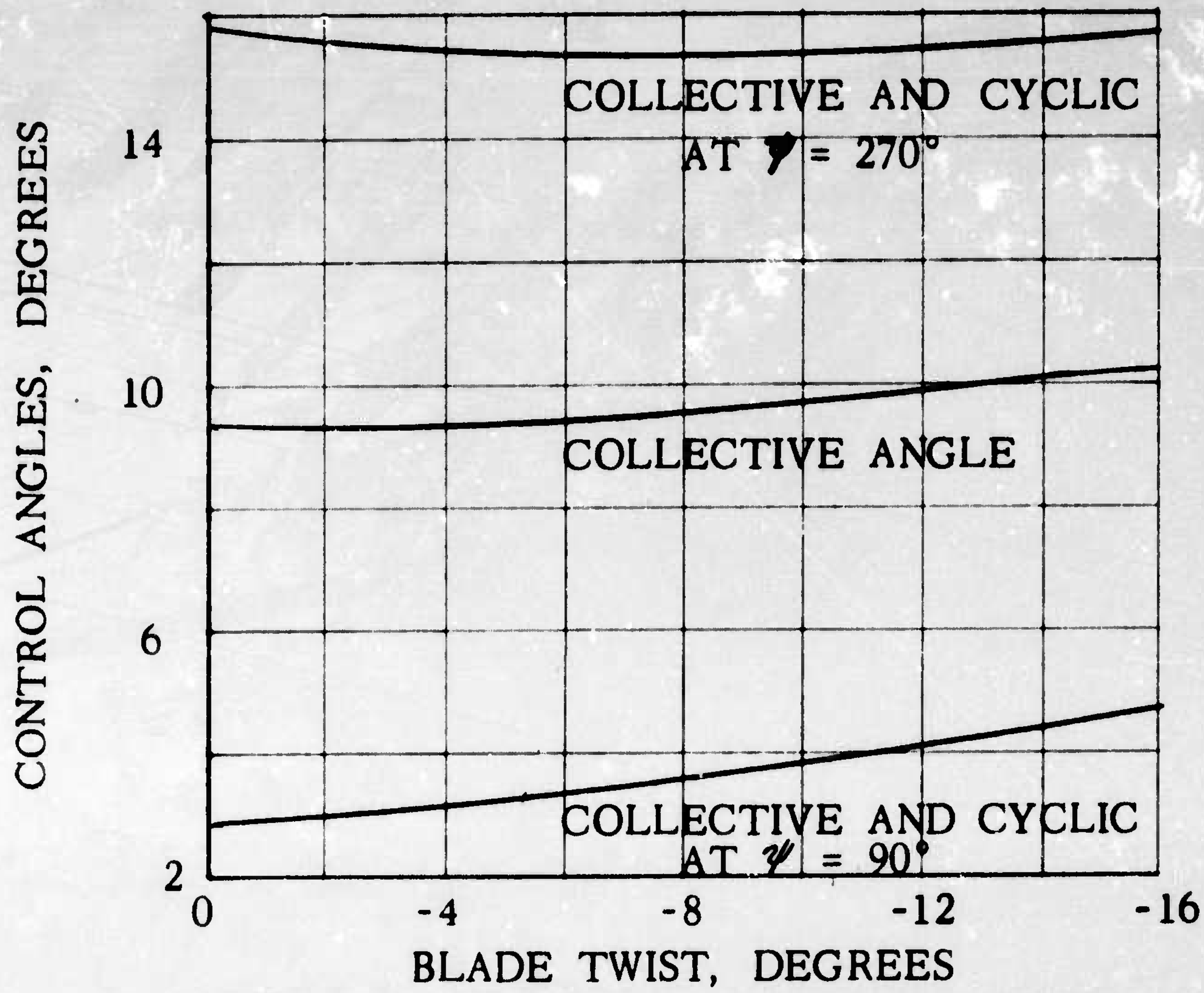


FIG. 7.43 CHANGE IN CONTROL ANGLES WITH BLADE TWIST

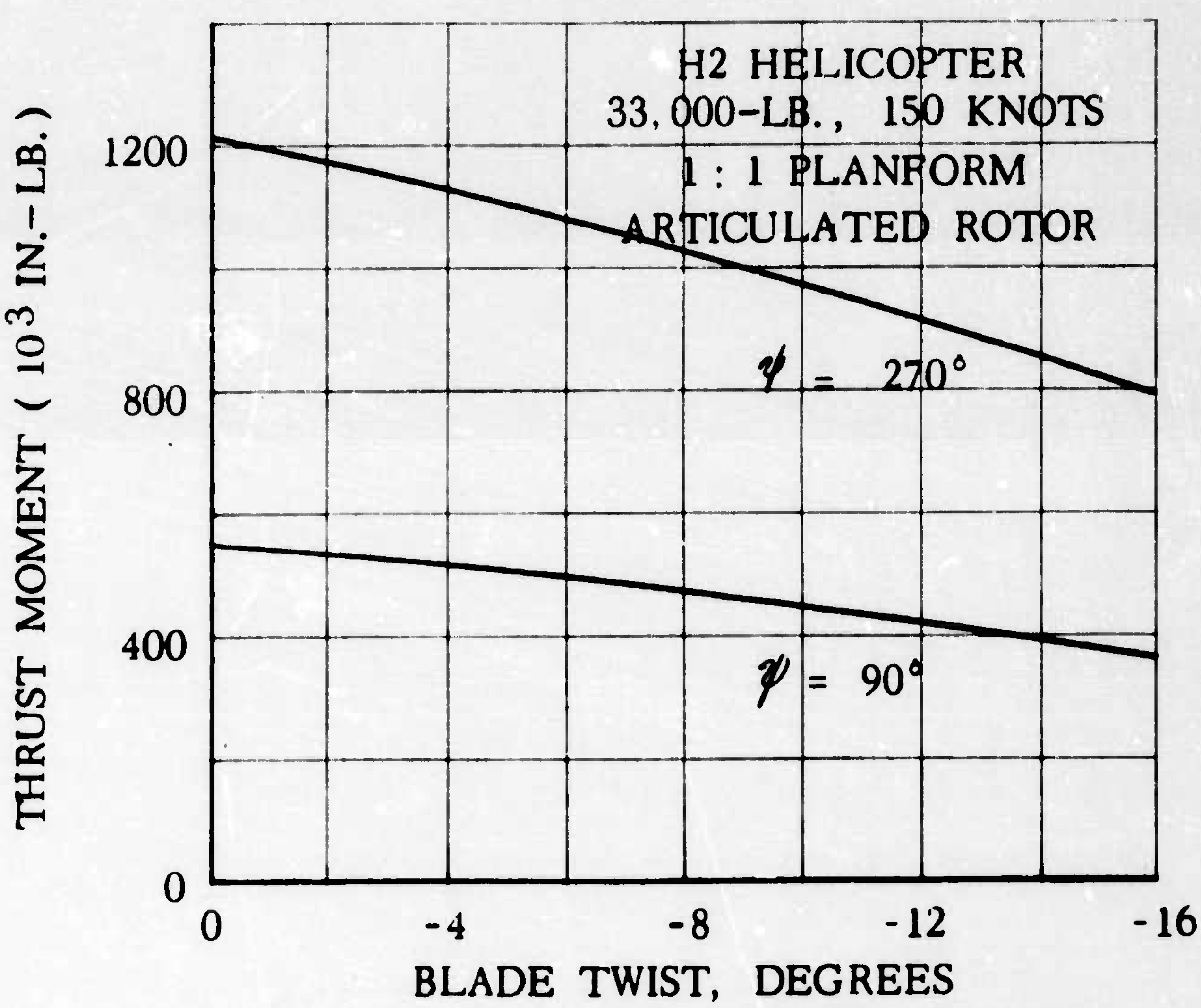


FIG. 7.44 CHANGE IN THRUST MOMENT WITH BLADE TWIST

H2 HELICOPTER
33, 000-LB., 150 KNOTS
1 : 1 PLANFORM

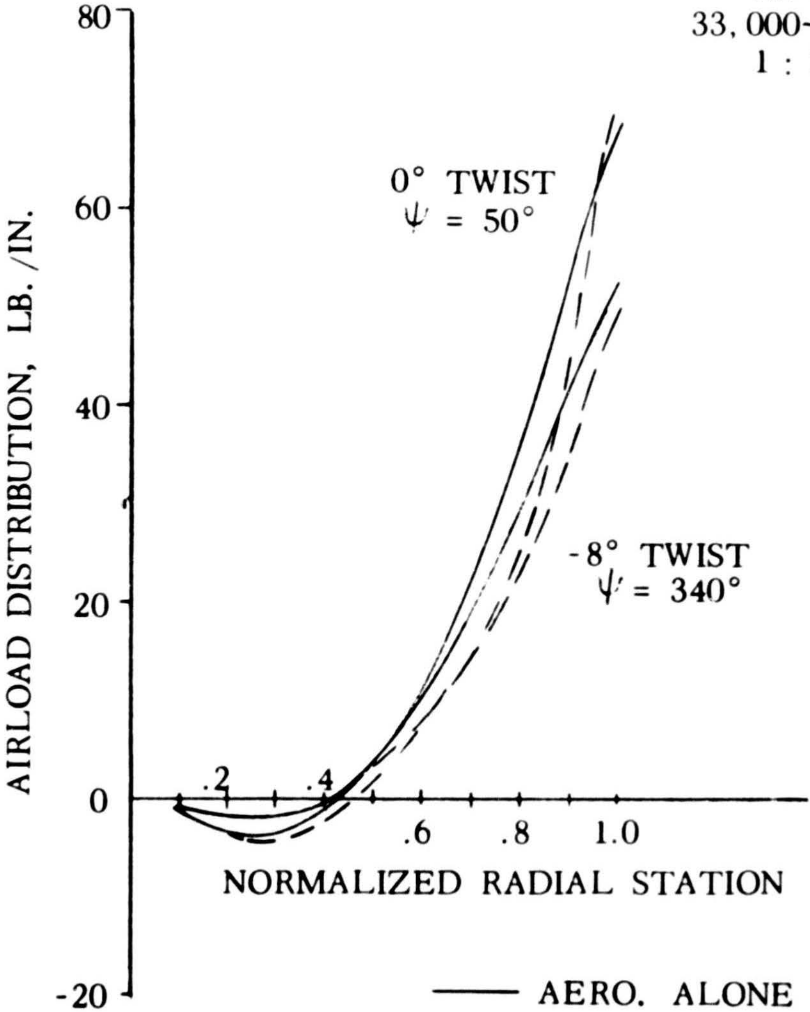


FIG. 7.45 EFFECT OF TWIST ON AIRLOAD DISTRIBUTION AT AZIMUTH POSITION OF MAXIMUM POSITIVE STRESS

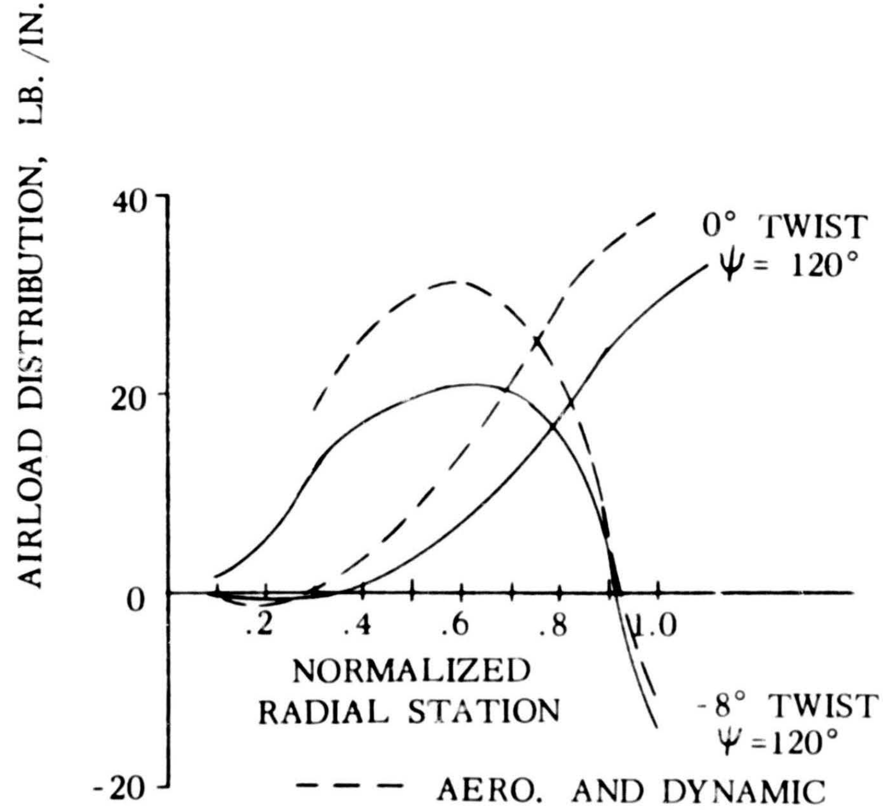


FIG. 7.46 EFFECT OF TWIST ON AIRLOAD DISTRIBUTION AT AZIMUTH POSITION OF MAXIMUM NEGATIVE STRESS

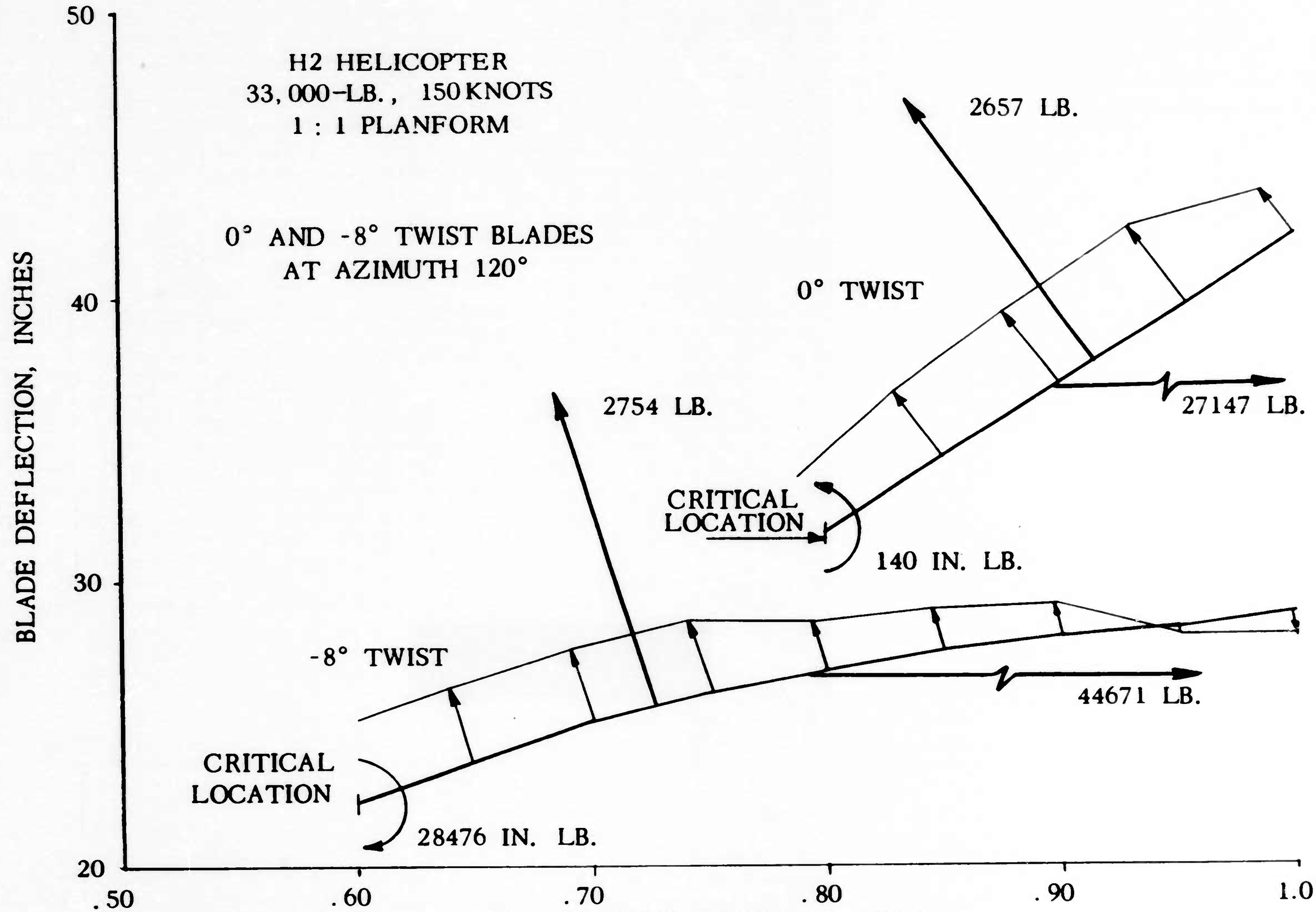
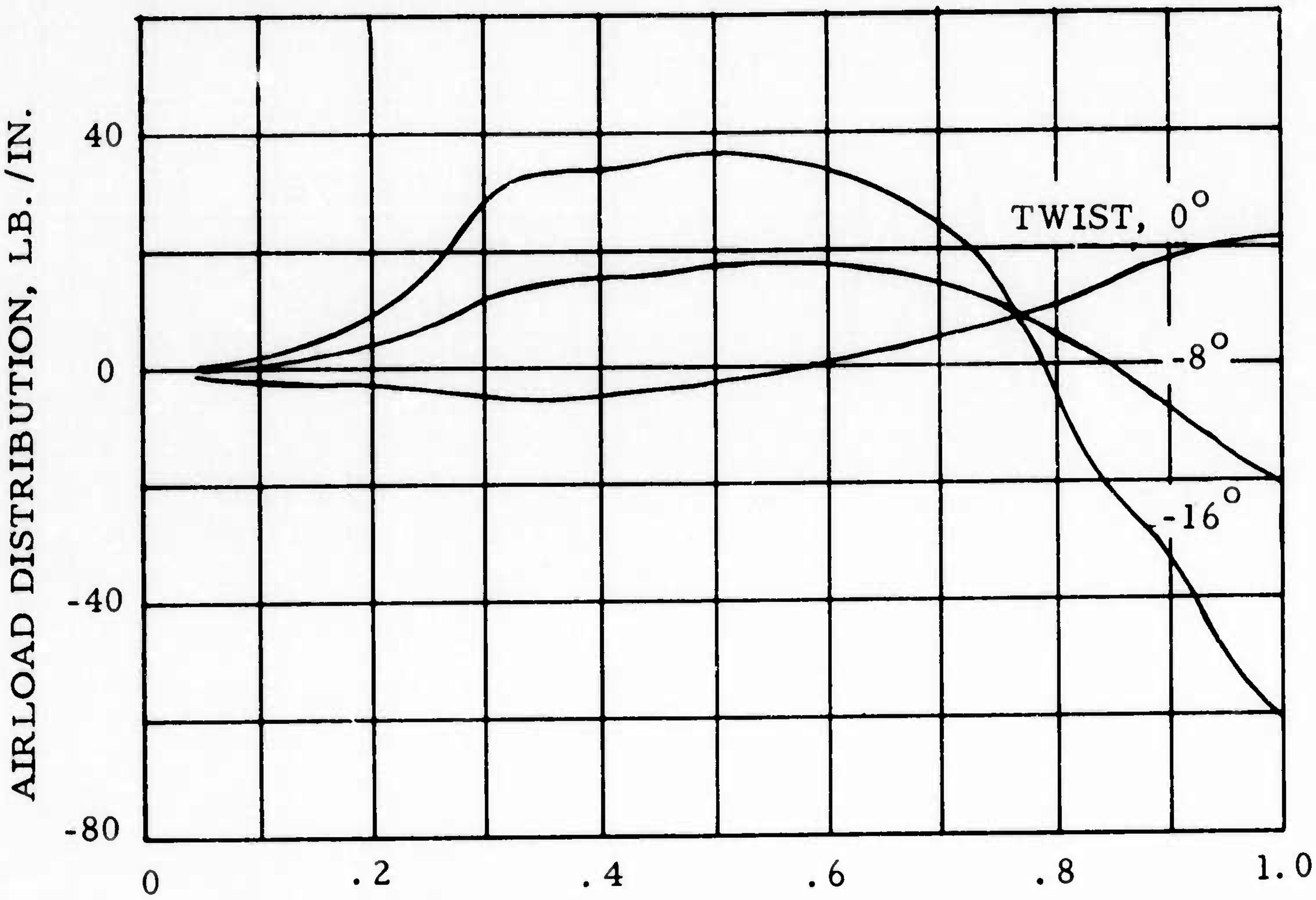
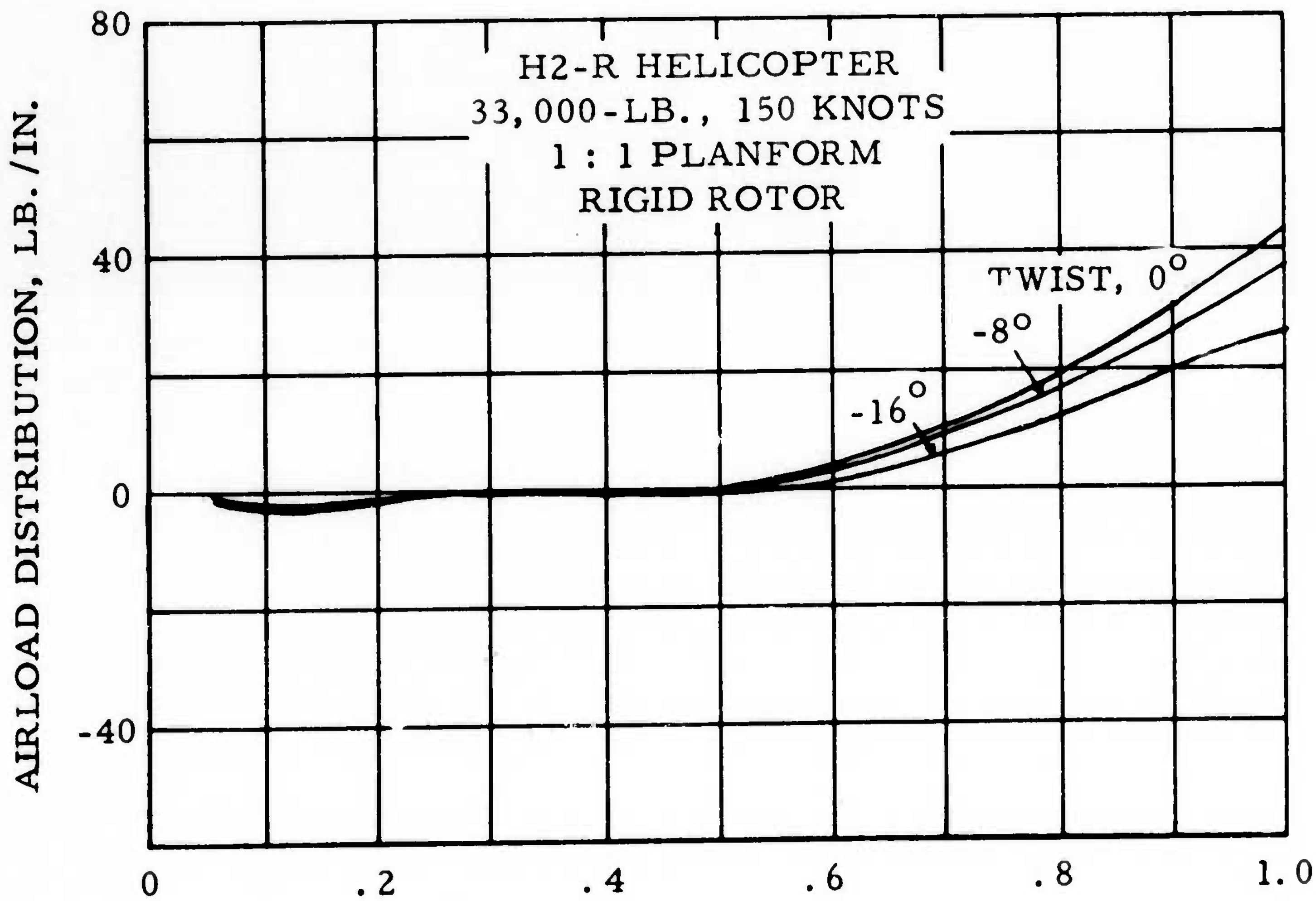


FIG. 7.47 STATIC ANALYSIS DIAGRAM



NORMALIZED RADIAL STATION

FIG. 7.48 CHANGE IN AIRLOADS WITH TWIST AT 90° AZIMUTH



NORMALIZED RADIAL STATION

FIG. 7.49 CHANGE IN AIRLOADS WITH TWIST AT 270° AZIMUTH

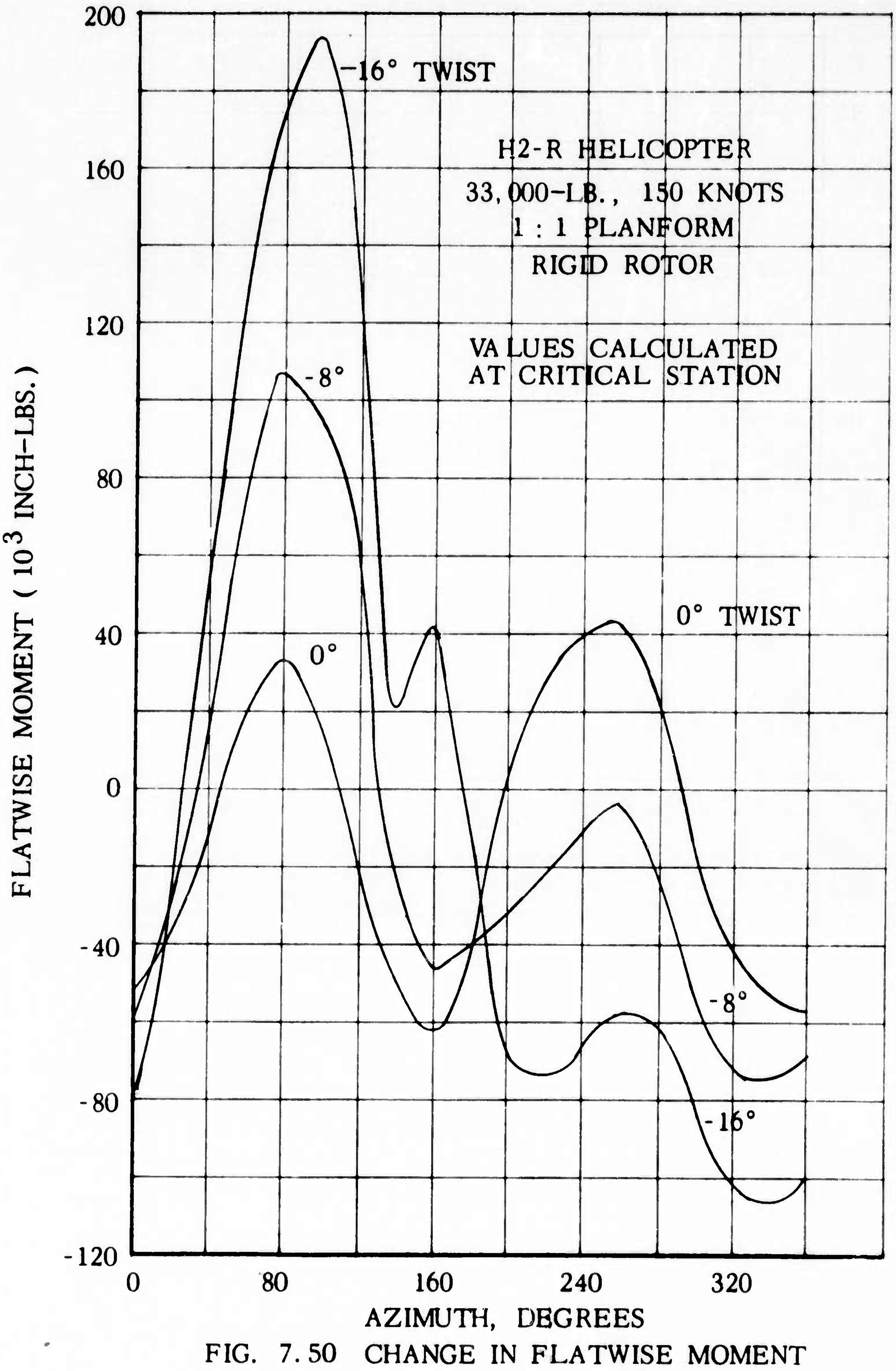


FIG. 7.50 CHANGE IN FLATWISE MOMENT WITH TWIST AND AZIMUTH

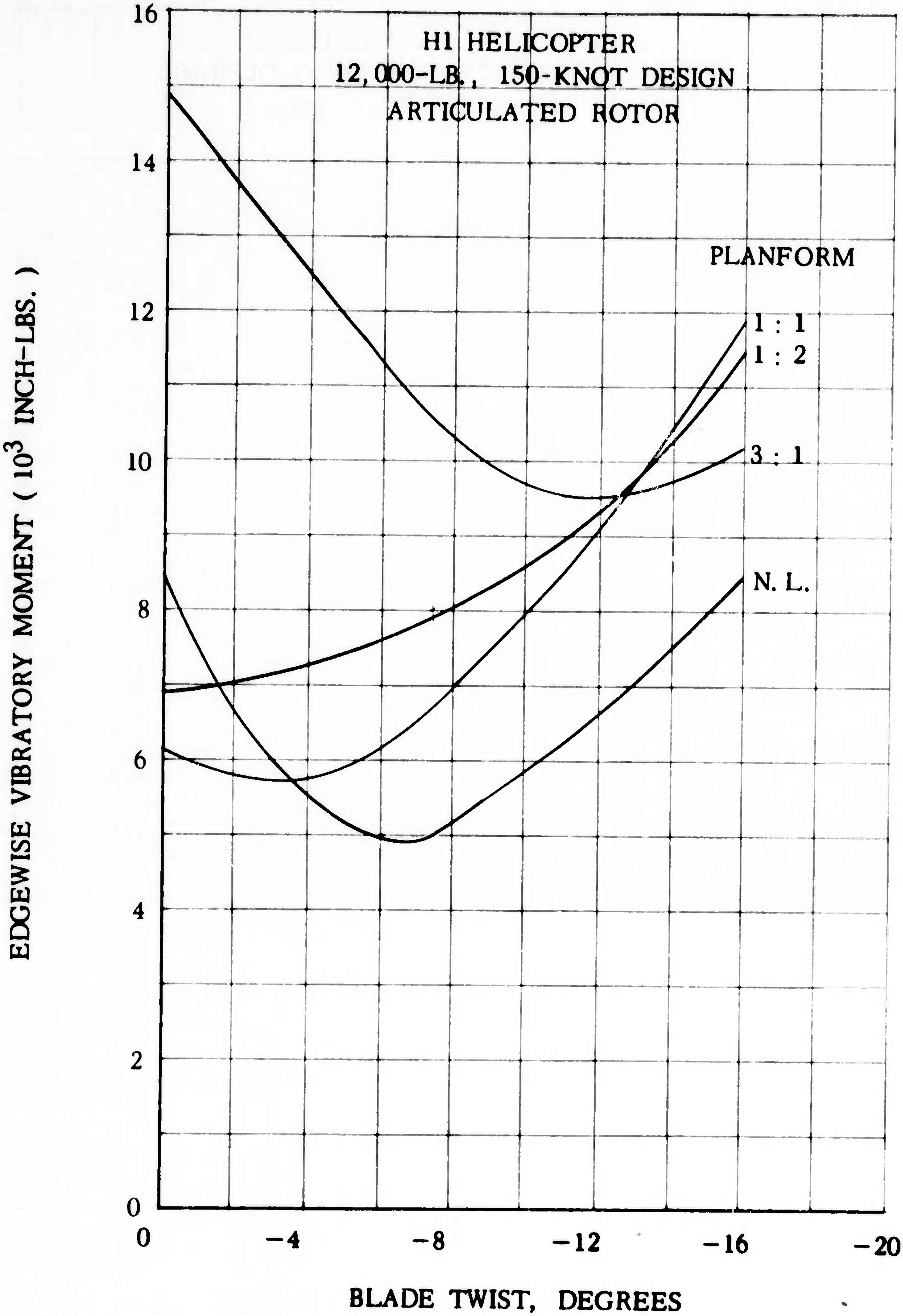


FIG.7.51 EFFECT OF TWIST ON EDGEWISE MOMENT

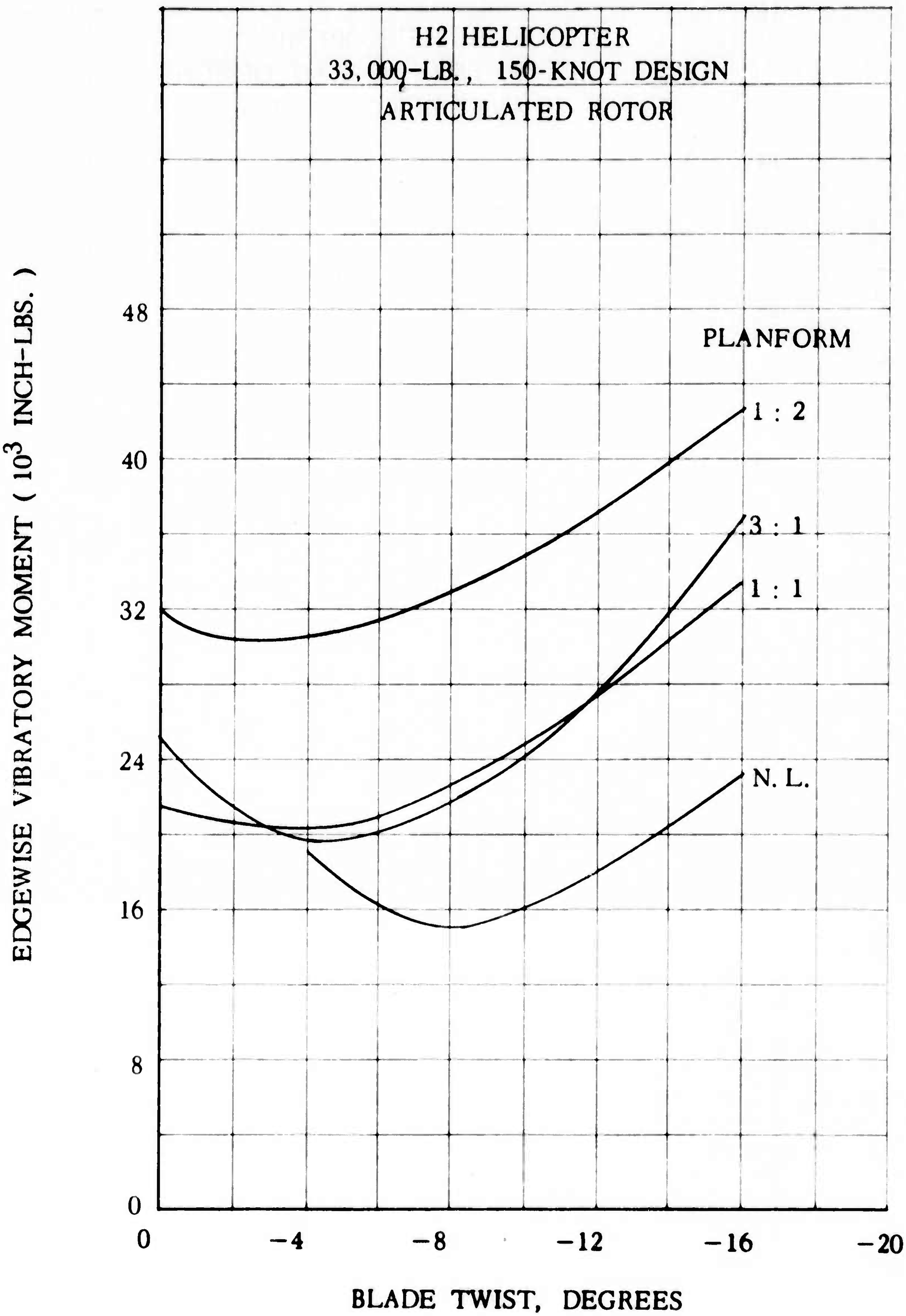


FIG. 7.52 EFFECT OF TWIST ON EDGEWISE MOMENT

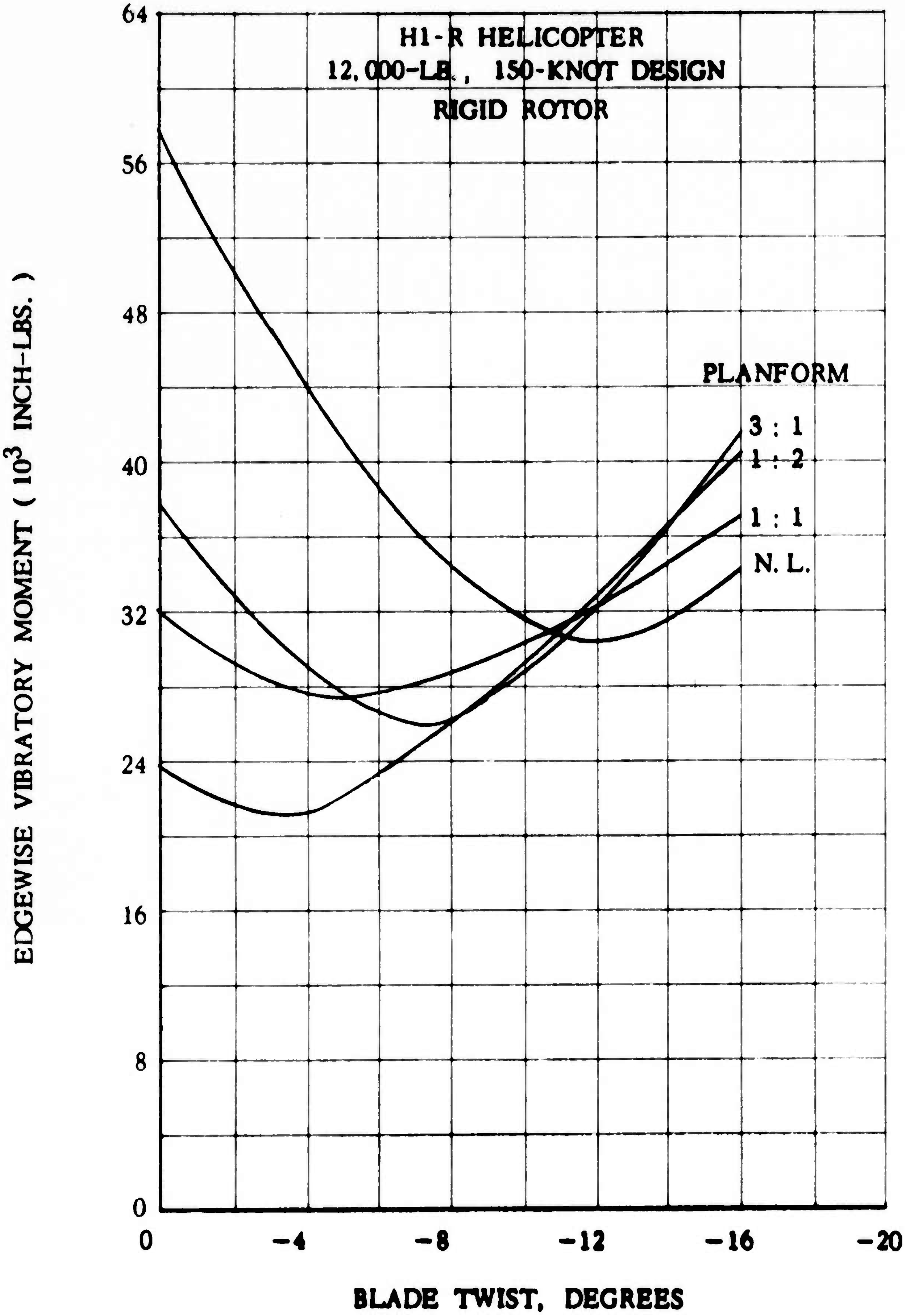


FIG.7.53 EFFECT OF TWIST ON EDGEWISE MOMENT

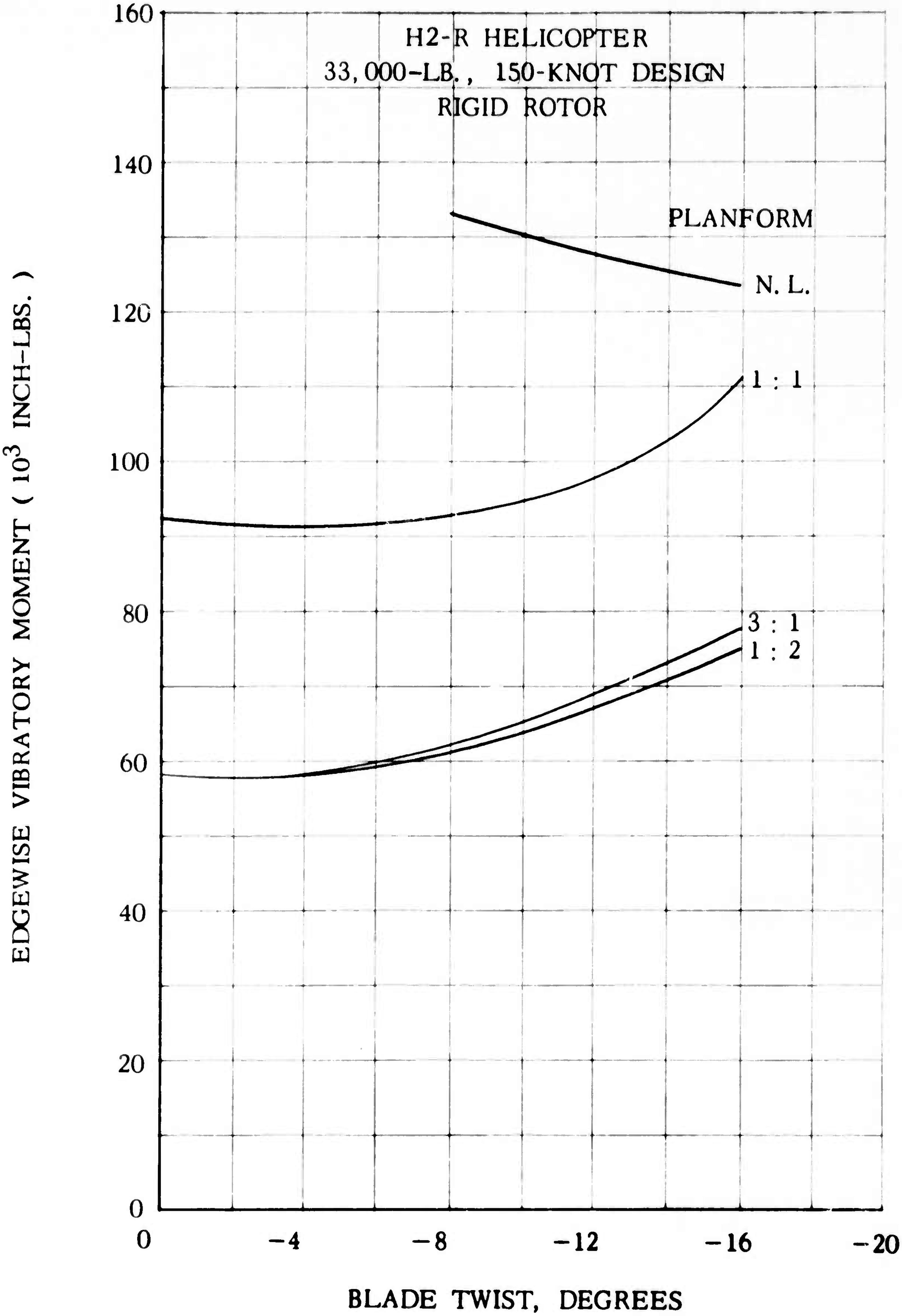


FIG. 7.54 EFFECT OF TWIST ON EDGEWISE MOMENT

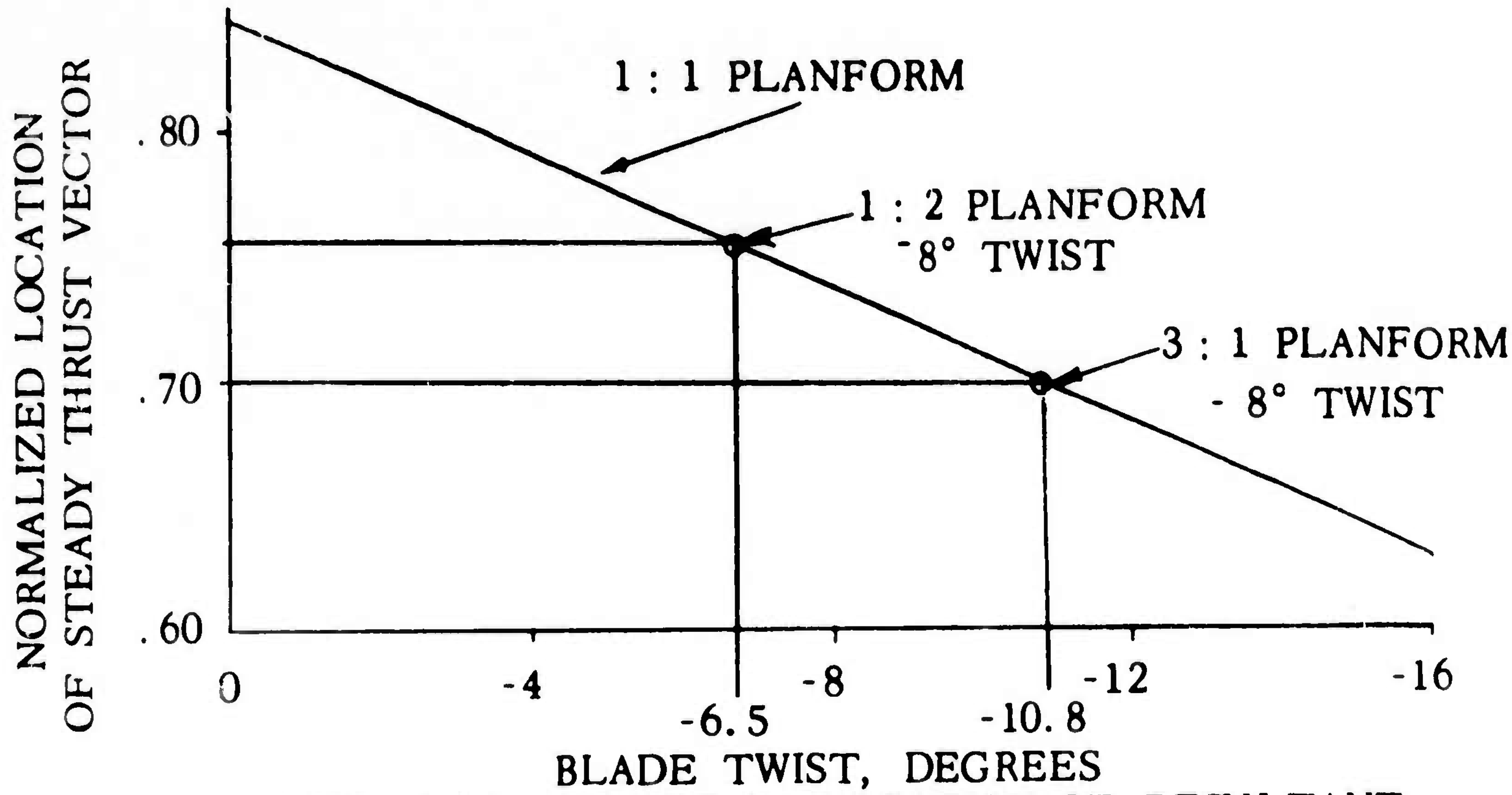


FIG. 7.55 CHANGE IN LOCATION OF RESULTANT STEADY THRUST VECTOR WITH CHANGE IN TWIST

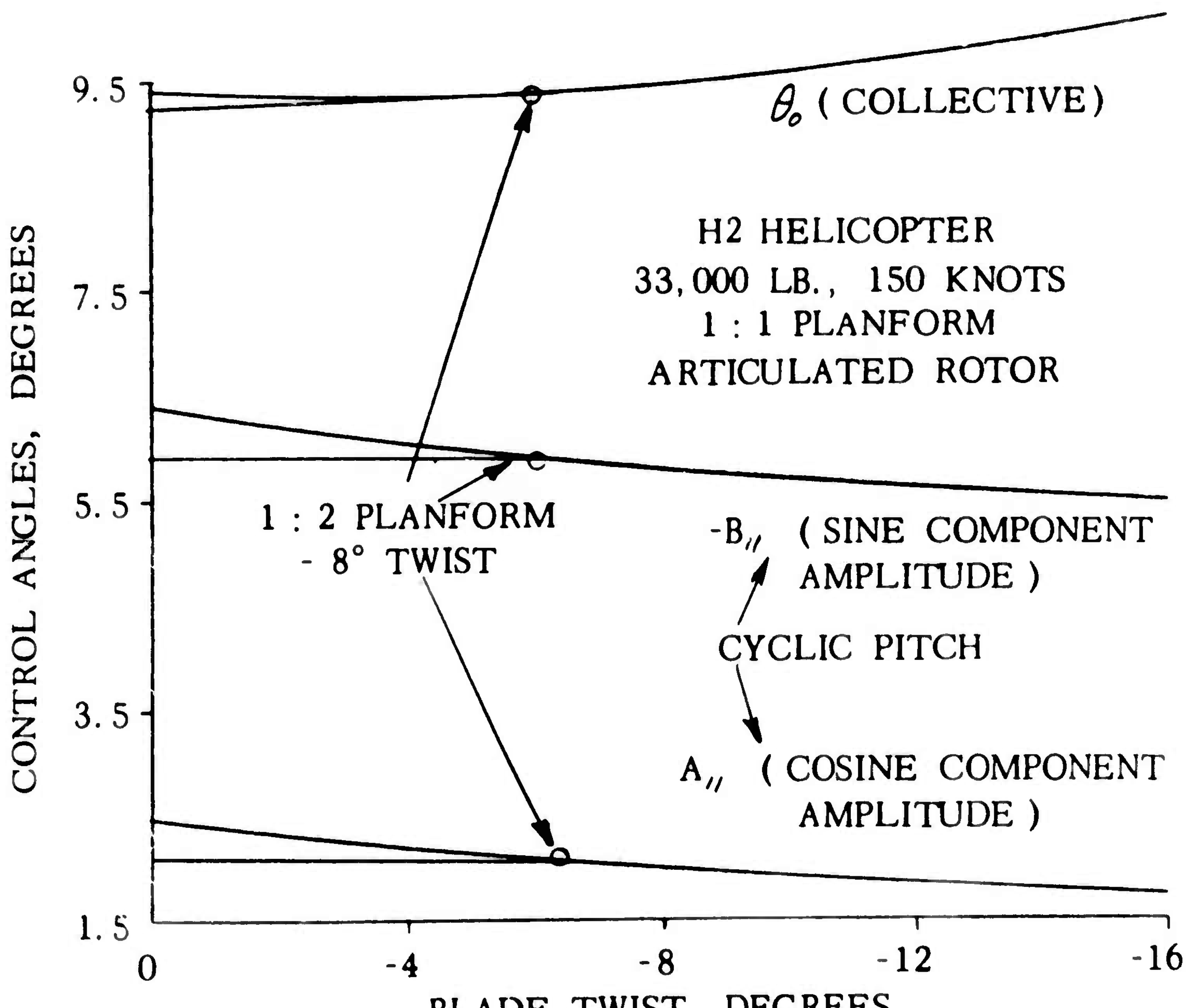


FIG. 7.56 CHANGE IN CONTROL ANGLES WITH CHANGE IN TWIST

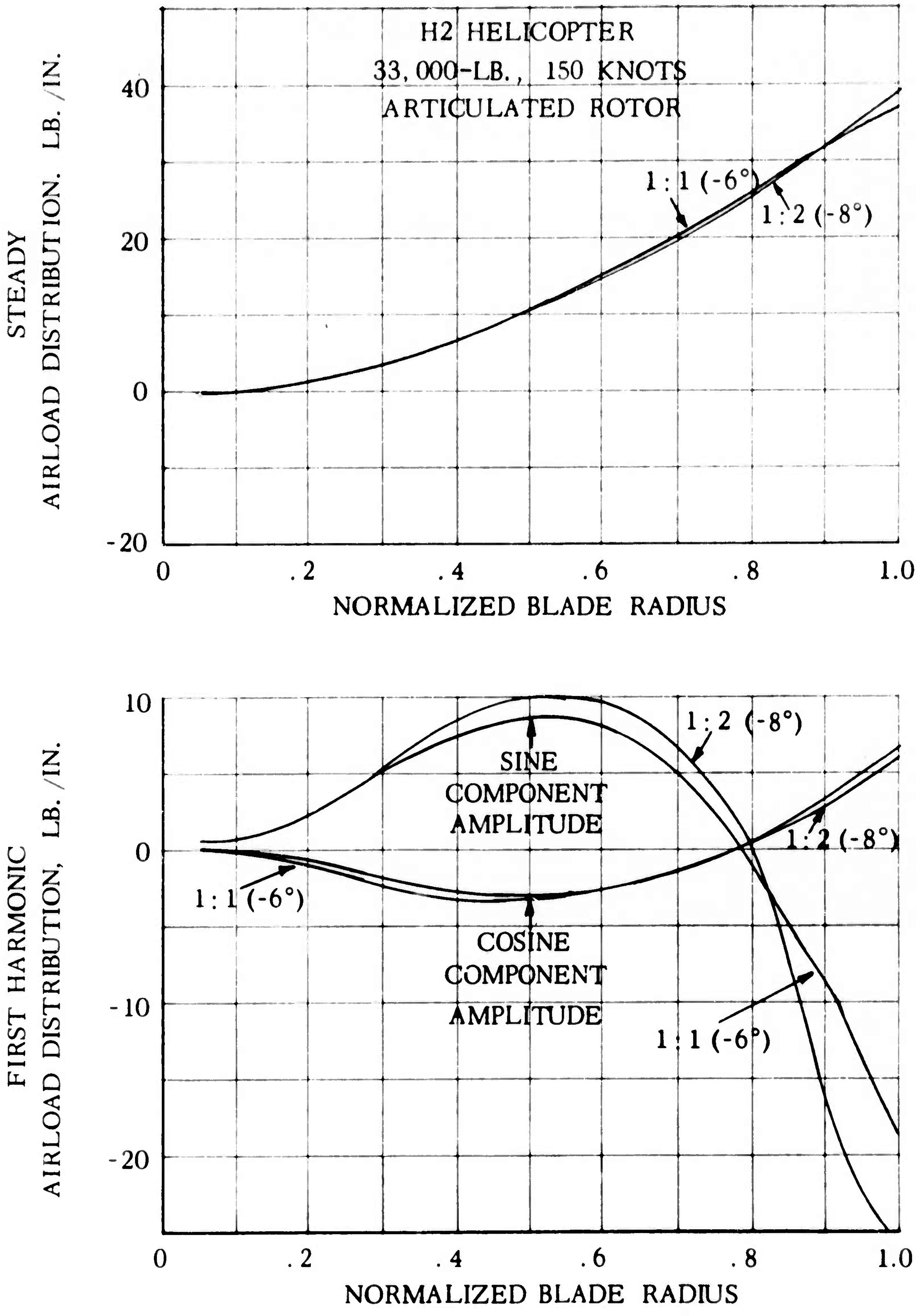


FIG. 7.57 CHANGE IN AIRLOAD DISTRIBUTION WITH TWIST

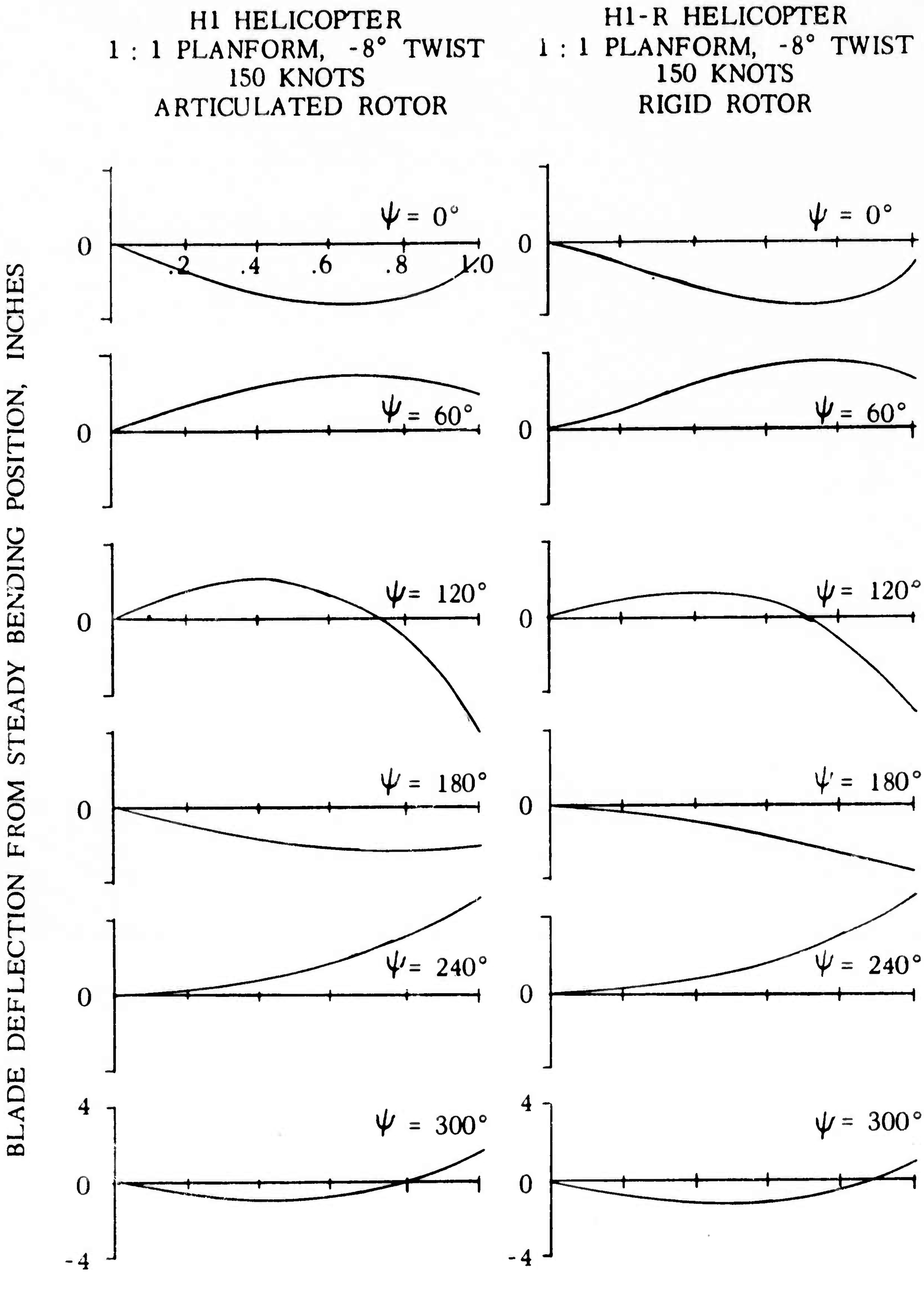


FIG. 7.58 CHANGE IN BLADE DEFLECTION WITH AZIMUTH

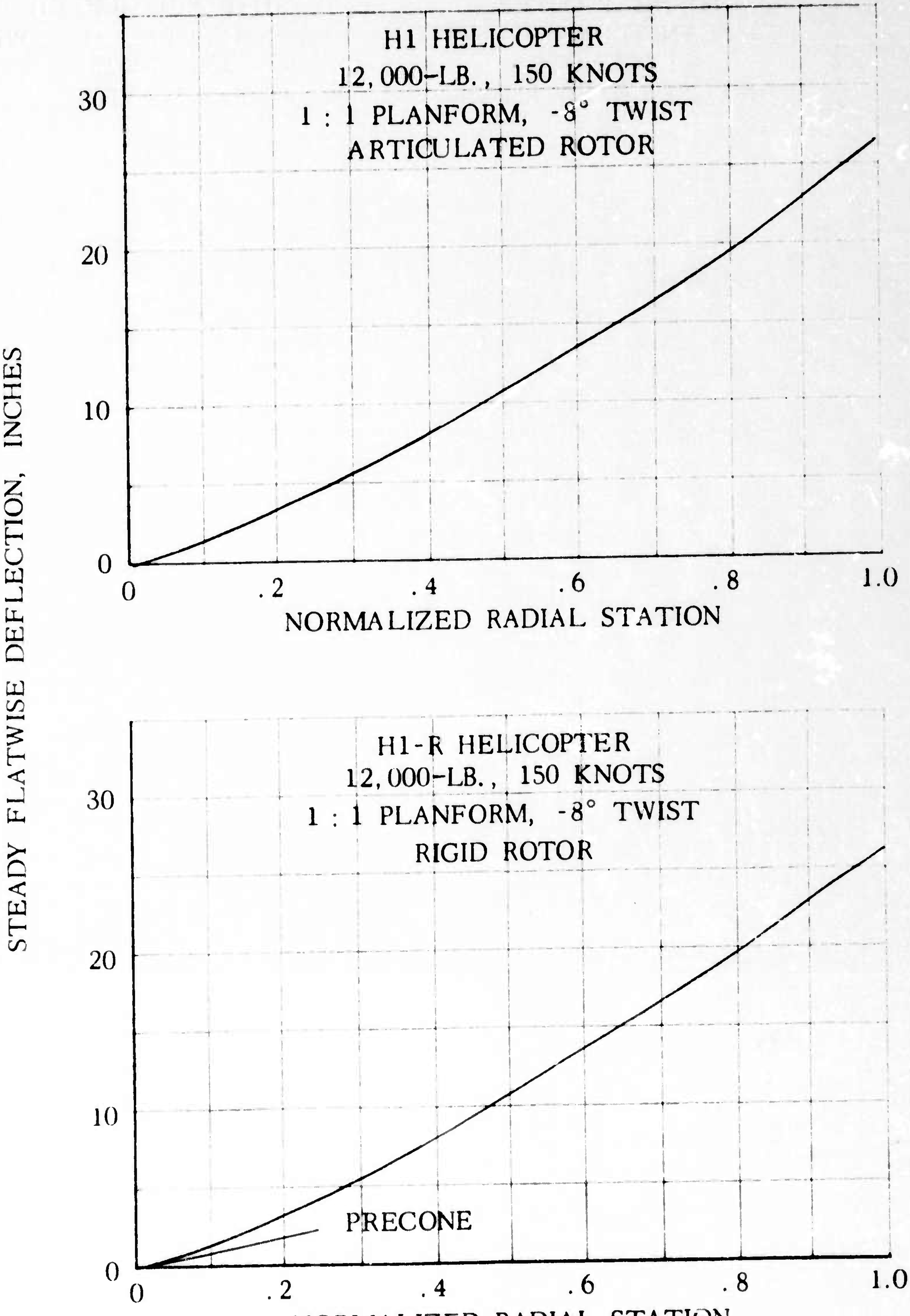


FIG. 7.59 STEADY BENDING RESPONSE

8. AERODYNAMIC PARAMETER VARIATIONS

A. FUSELAGE DRAG

Tables 2.7 and 2.8 give the schedule of fuselage drag variations investigated in the program. Rotor power with drag change is plotted versus airspeed in Figure 8.1. As expected, the plot shows both increased power with forward speed and increased power with increased fuselage drag. Similar trends are shown for both high-gross-weight and low-gross-weight helicopters.

Presented in Figures 8.2 through 8.5 are effects of fuselage drag variation on flatwise blade vibratory moments. Results are given for both high-gross-weight and low-gross-weight helicopters with articulated and rigid rotor systems. With equivalent changes in fuselage drag, smaller vibratory moment variations were noted for the articulated than for the rigid rotor system. For gross weights, airspeeds, and blade systems considered, no consistent trend of moment increase or decrease with change in drag was observed.

B. VARIATIONS IN ROTOR SPEED

Variations in rotor rpm were carried out according to the schedule given in Table 2.2. Shown in Figures 8.10 and 8.11 are effects of rpm changes on rotor power and blade moments with airspeed held constant at 250 knots. Results are shown for both the C3 and C3-R compound helicopters. Observe that while there is a decrease in vibratory blade moment with increase in rpm, there is a corresponding increase in power required. Again, stress and power requirements are incompatible, and the design solution must be a compromise of the two. Also, note the sharp gradients of the curves. These indicate that rpm variations at high speeds for compound helicopters will result in sharp changes in power requirements and blade stress.

Effects of airspeed and rpm variations are shown in Figures 8.6 through 8.9. Plotted are resulting power and vibratory bending moments for the three rotor speeds considered. Observe that slopes of the power-rotor speed curves and stress-rotor speed curves increase with increase in airspeed. This means that the power-stress compromise becomes more critical as airspeed increases.

C. ALTITUDE VARIATIONS

The schedule of altitude conditions is presented in Tables 2.7 and 2.8. Figures 8.12 through 8.15 plot change in main rotor power required with altitude. Differences in sea-level power for articulated and rigid rotor helicopters are due to differences in blade twist. Design twist for rigid and articulated blades was based upon standard design practice of respective manufacturers.

Changes in blade vibratory moments with altitude are shown in Figures 8.16 through 8.19. Results which are presented take into account change in fuselage attitude with altitude, as well as air density and Mach number effects. Change in fuselage attitude affects both equivalent flat-plate area of the fuselage and rotor lift requirements. Data showing the variation in fuselage lift and drag with airspeed and altitude are presented in Appendix A.

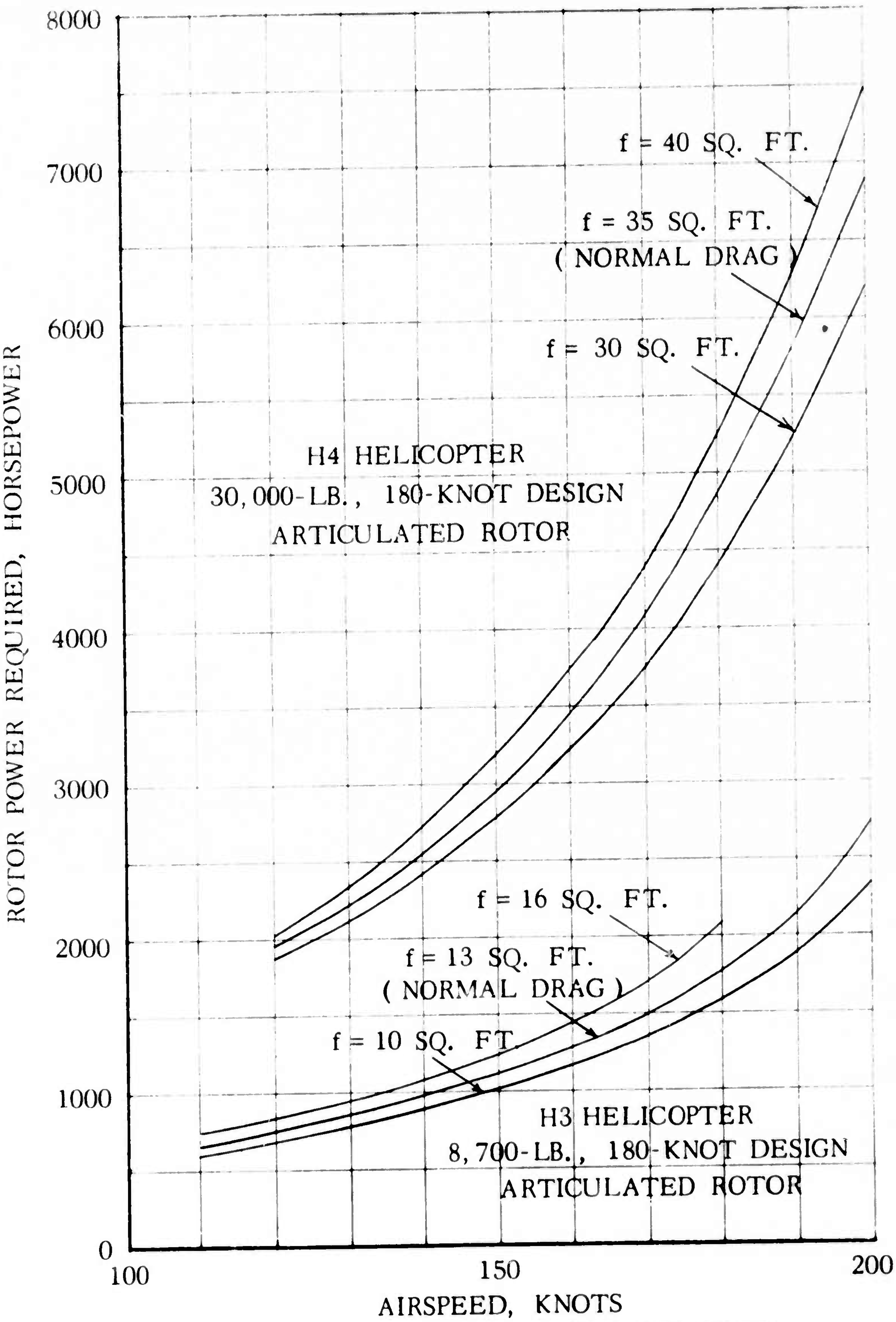


FIG. 8.1 CHANGE IN POWER REQUIRED WITH PARASITE DRAG

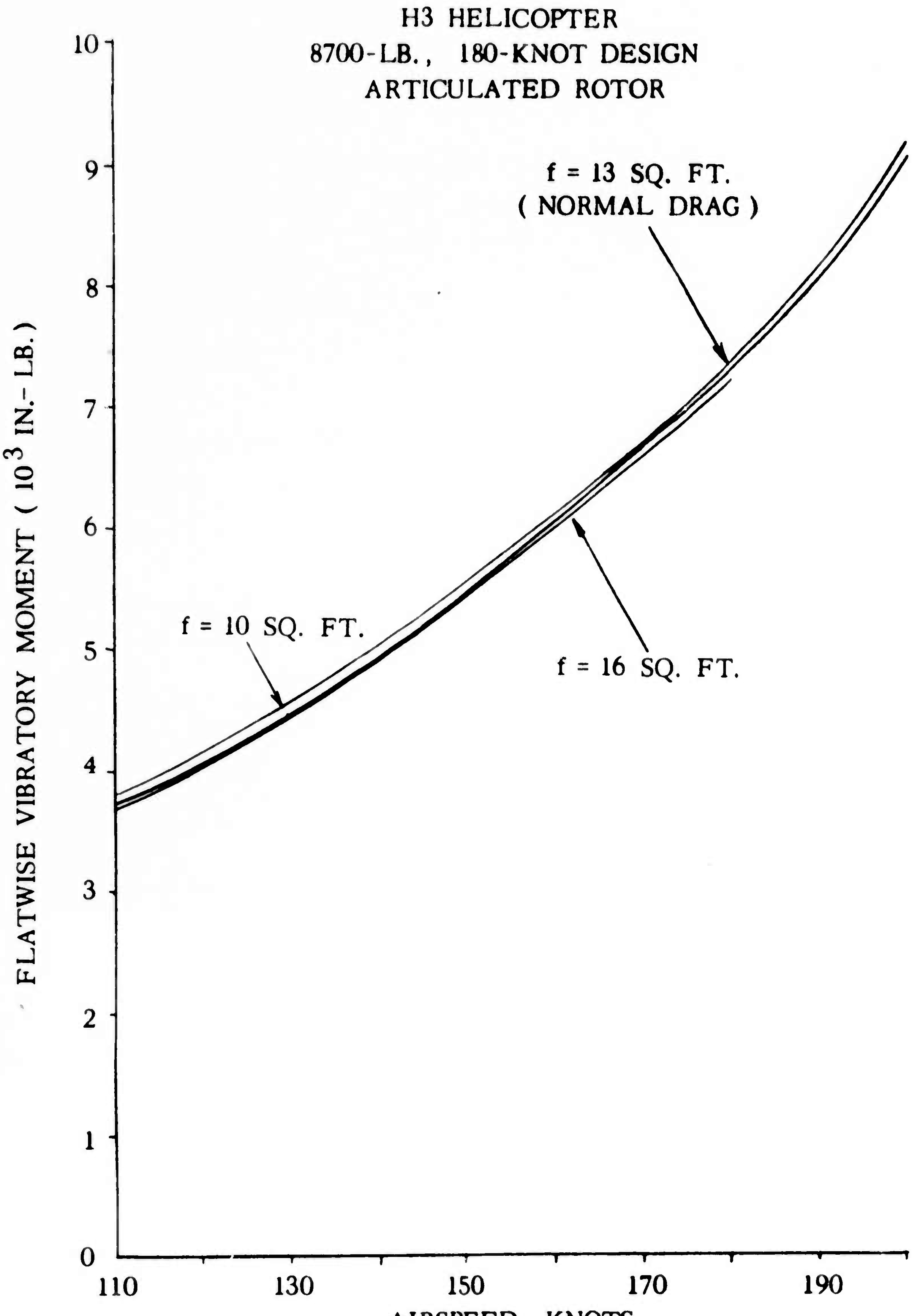


FIG. 8.2 CHANGE IN FLATWISE MOMENT WITH PARASITE DRAG

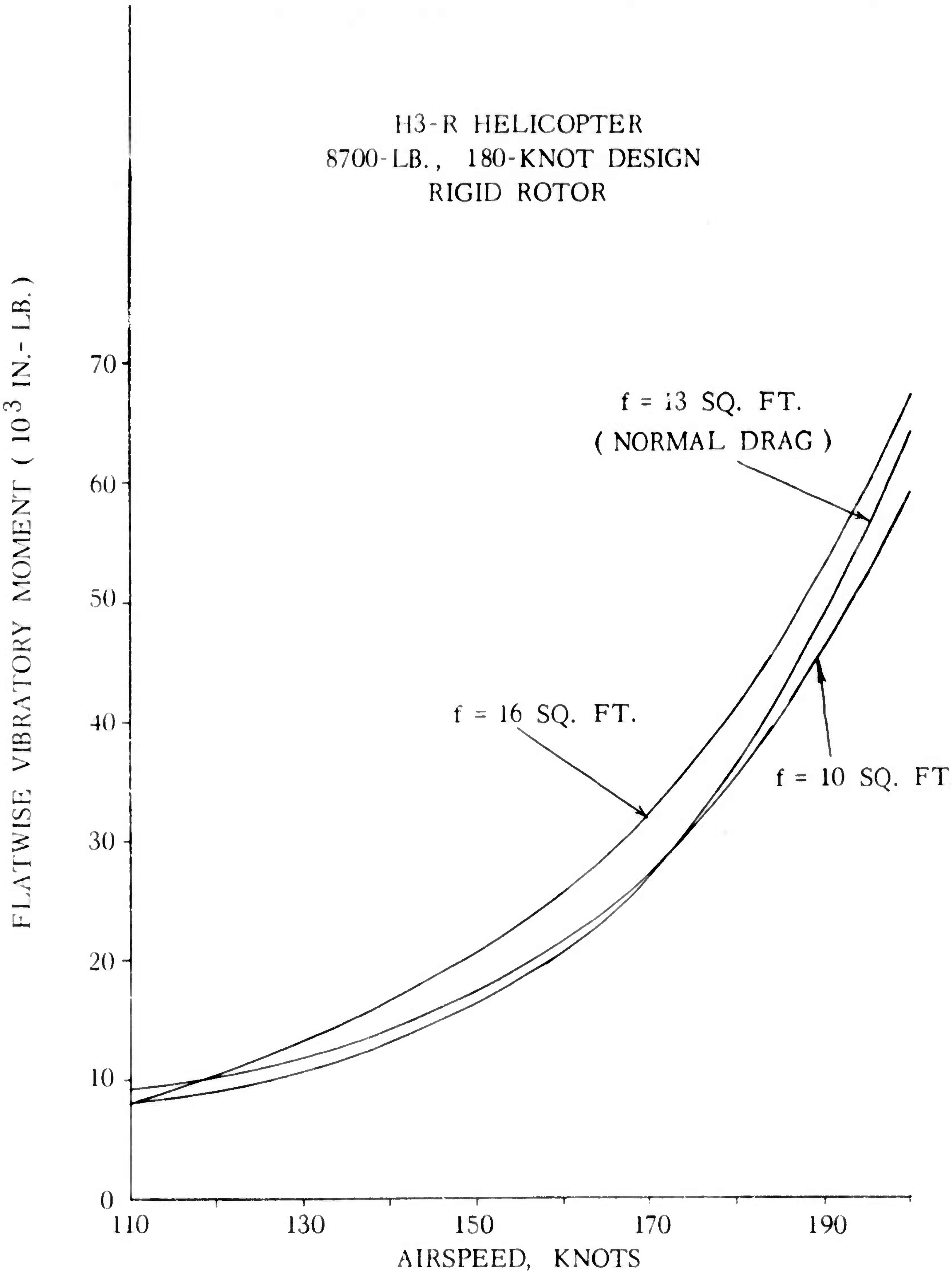


FIG. 8.3 CHANGE IN FLATWISE MOMENT WITH PARASITE DRAG

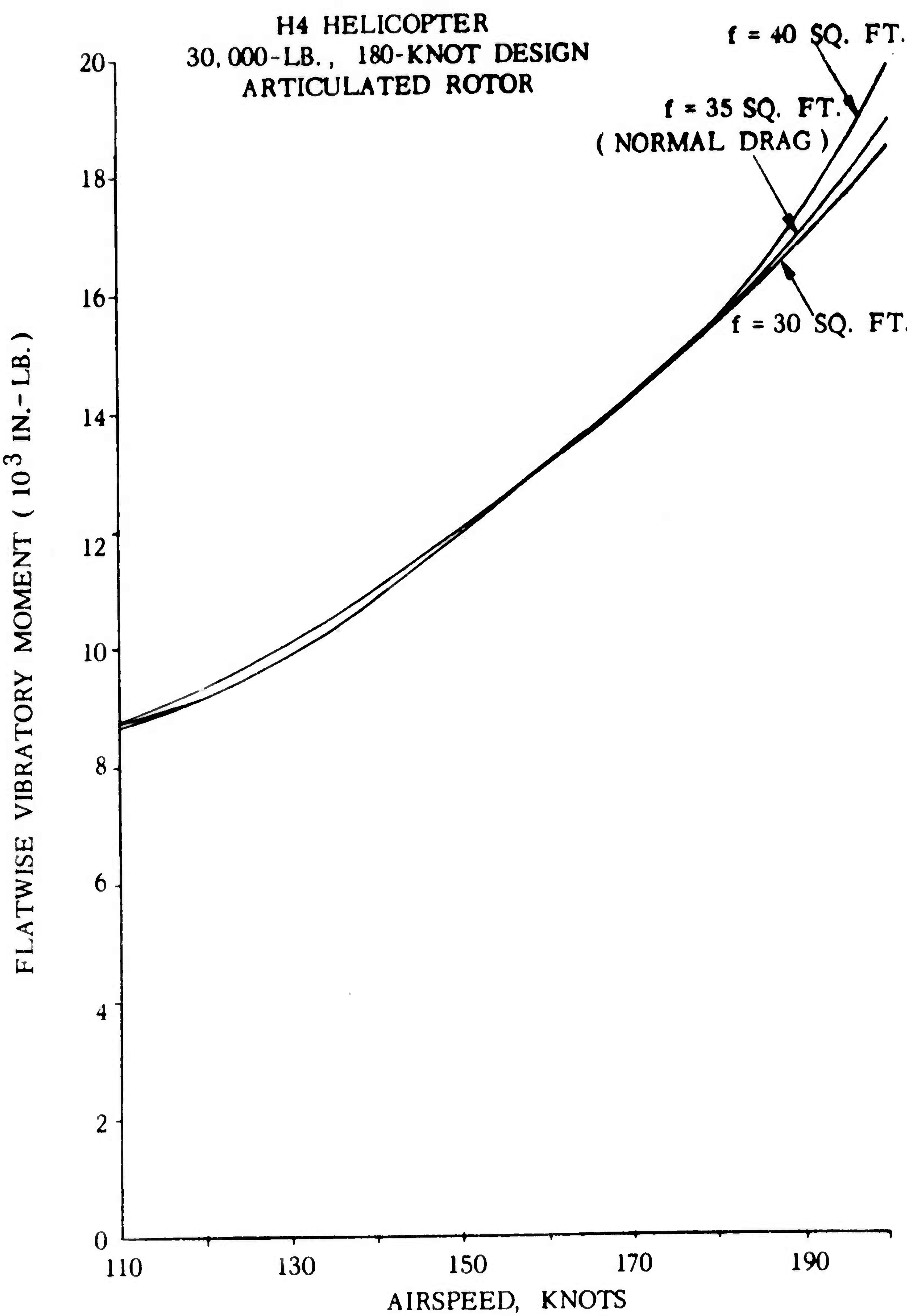


FIG. 8.4 CHANGE IN FLATWISE MOMENT WITH PARASITE DRAG

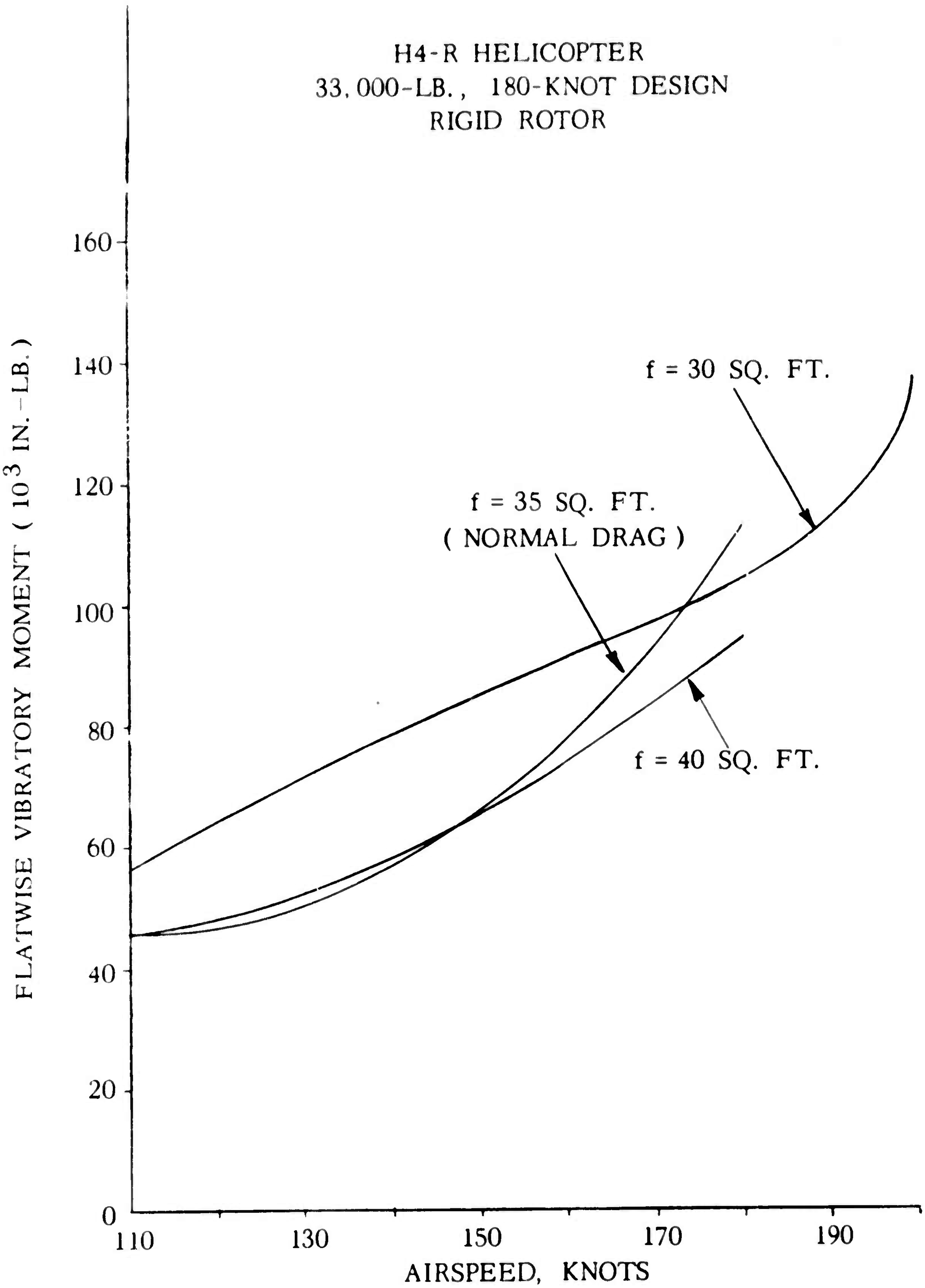


FIG. 8.5 CHANGE IN FLATWISE MOMENT WITH PARASITE DRAG

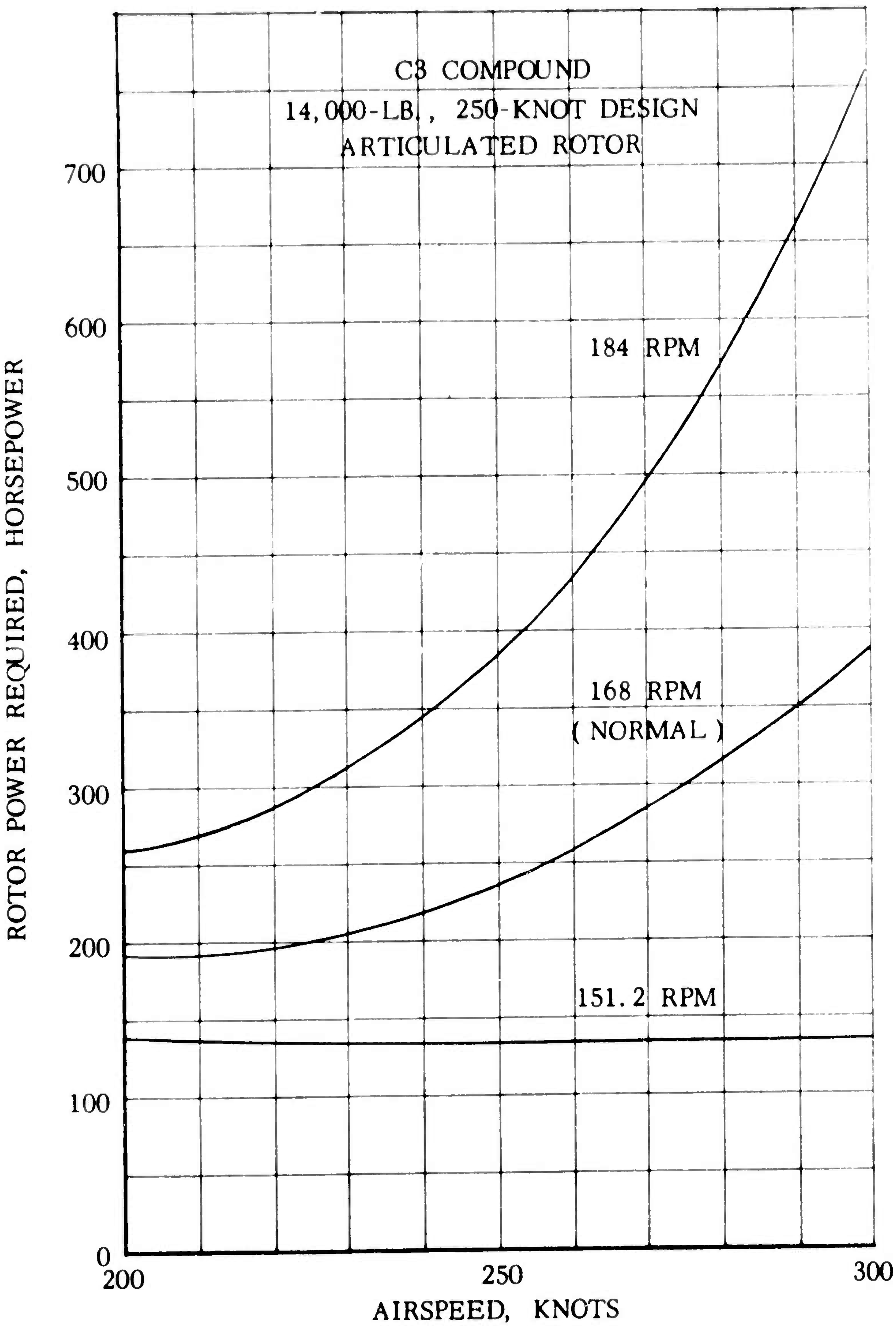


FIG. 8.6 CHANGE IN POWER REQUIRED WITH ROTOR SPEED

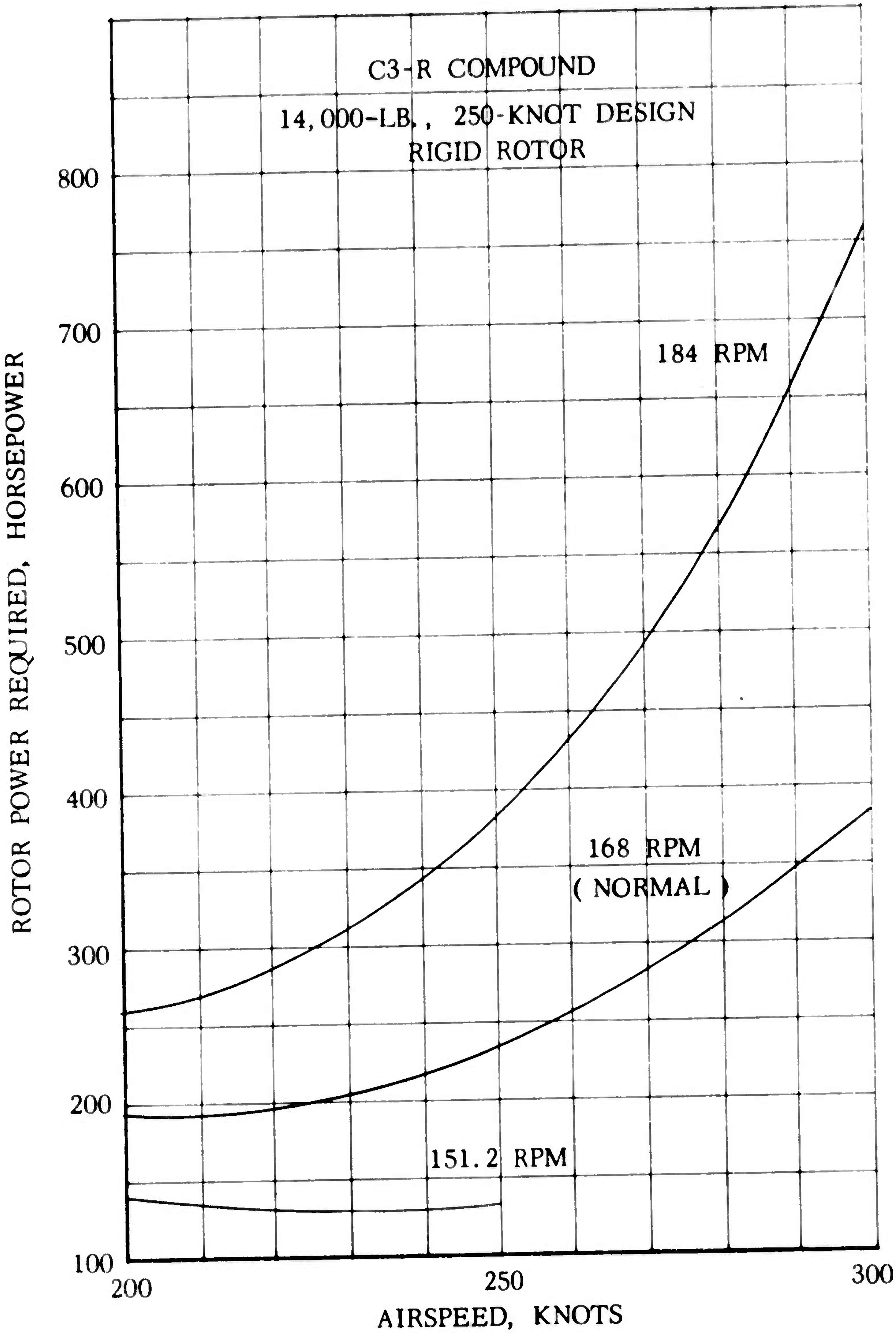


FIG. 8.7 CHANGE IN POWER REQUIRED WITH ROTOR SPEED

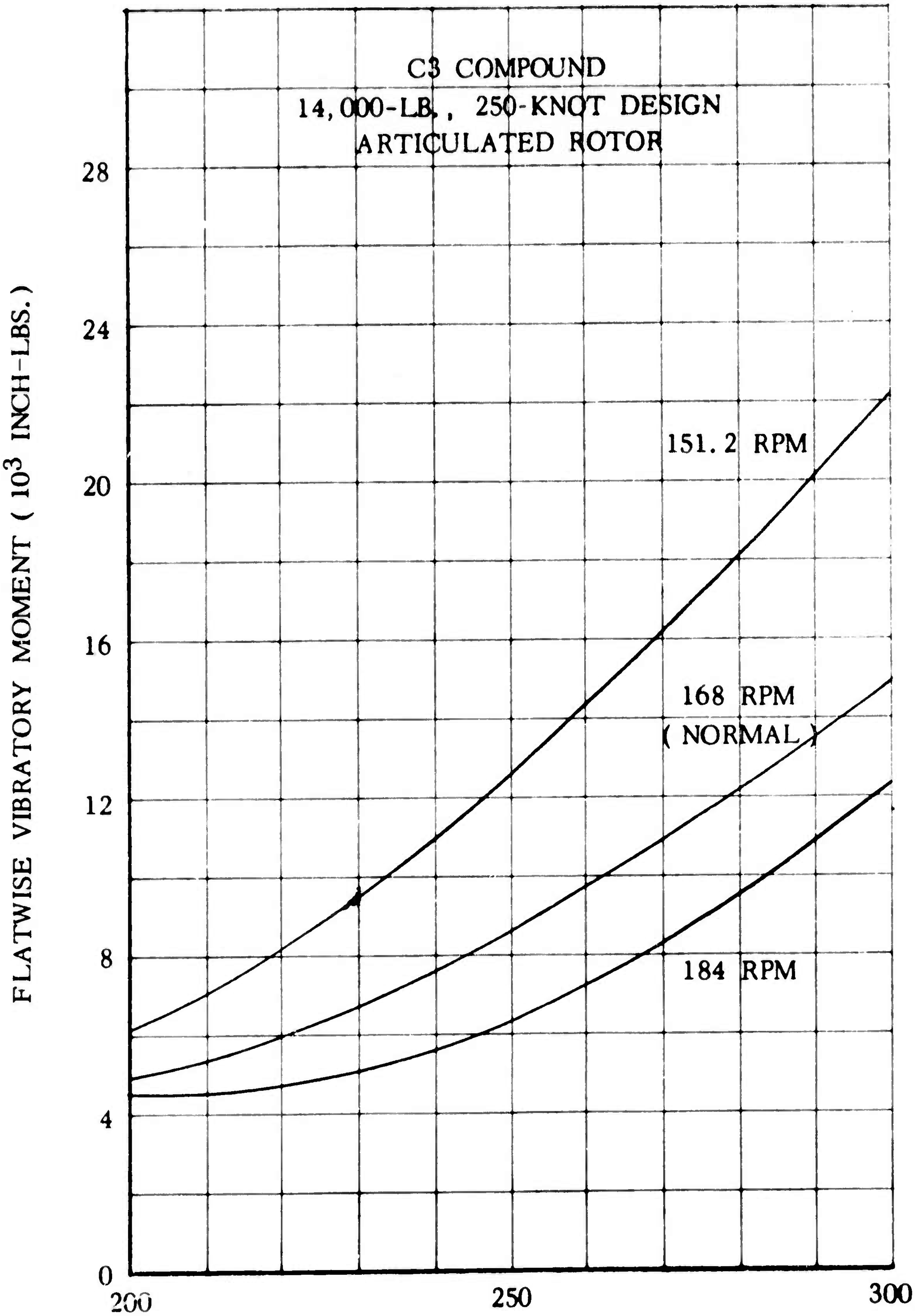


FIG. 8.8 CHANGE IN FLATWISE MOMENT WITH ROTOR SPEED

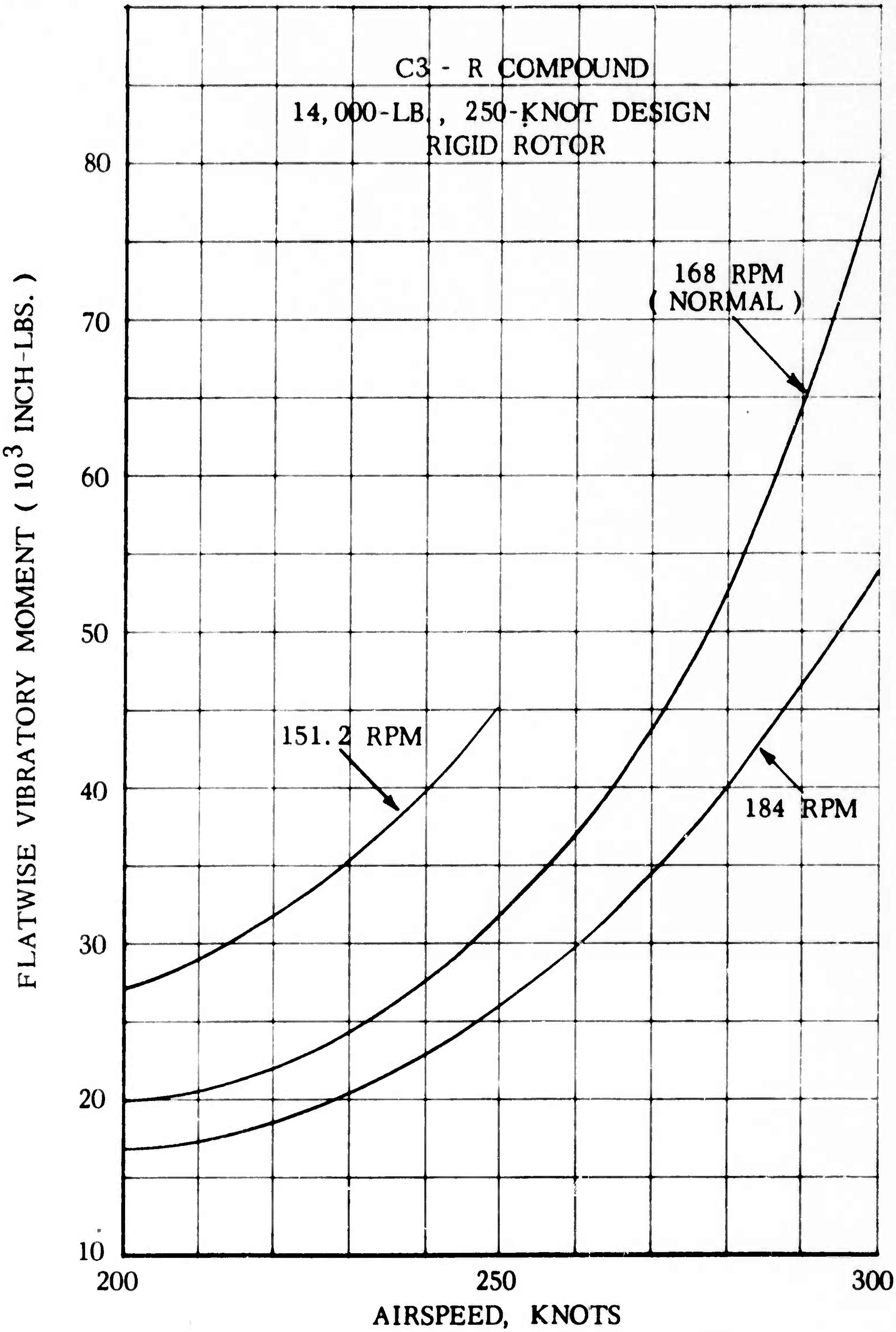
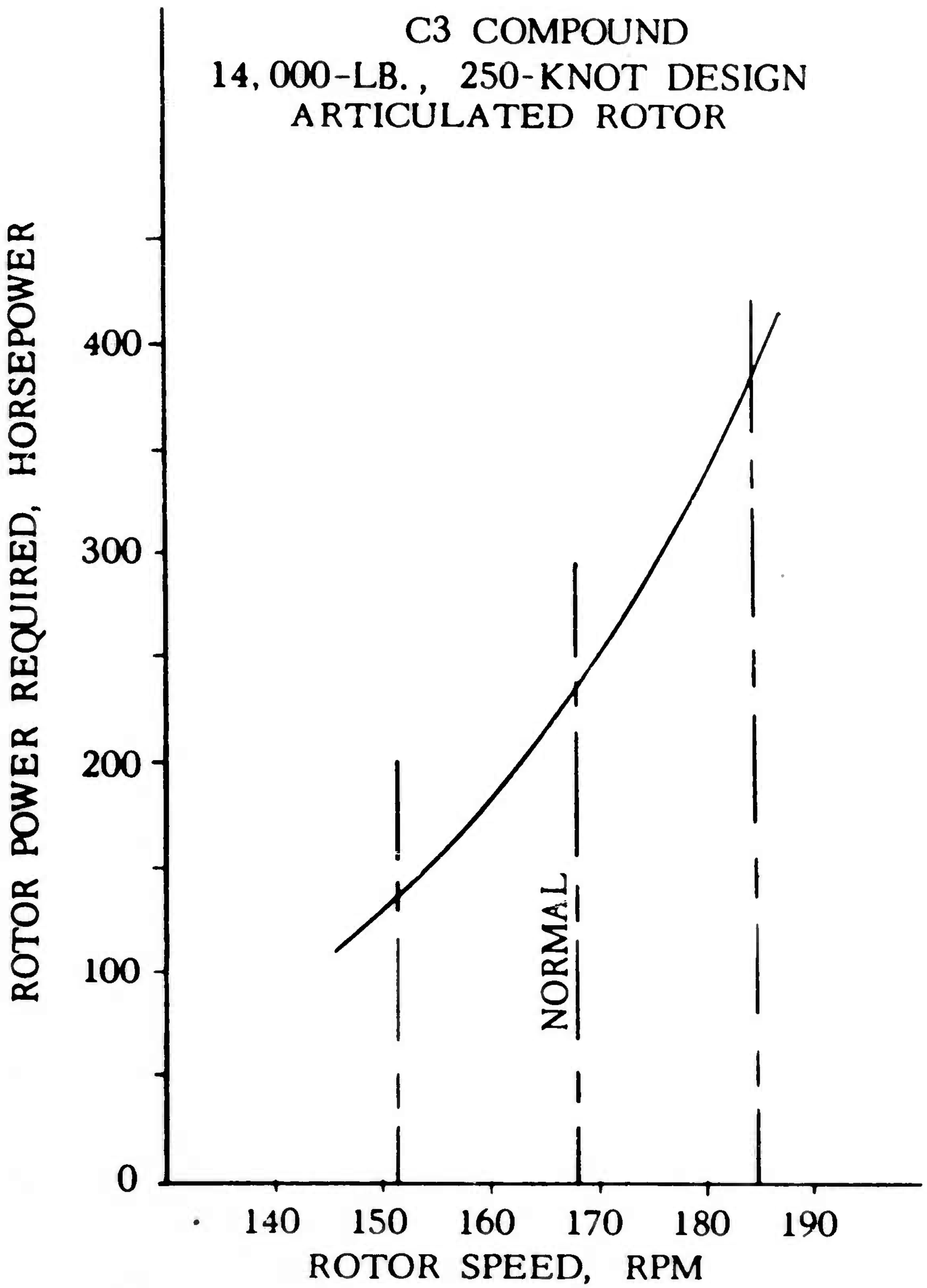


FIG. 8.9 CHANGE IN FLATWISE MOMENT WITH ROTOR SPEED



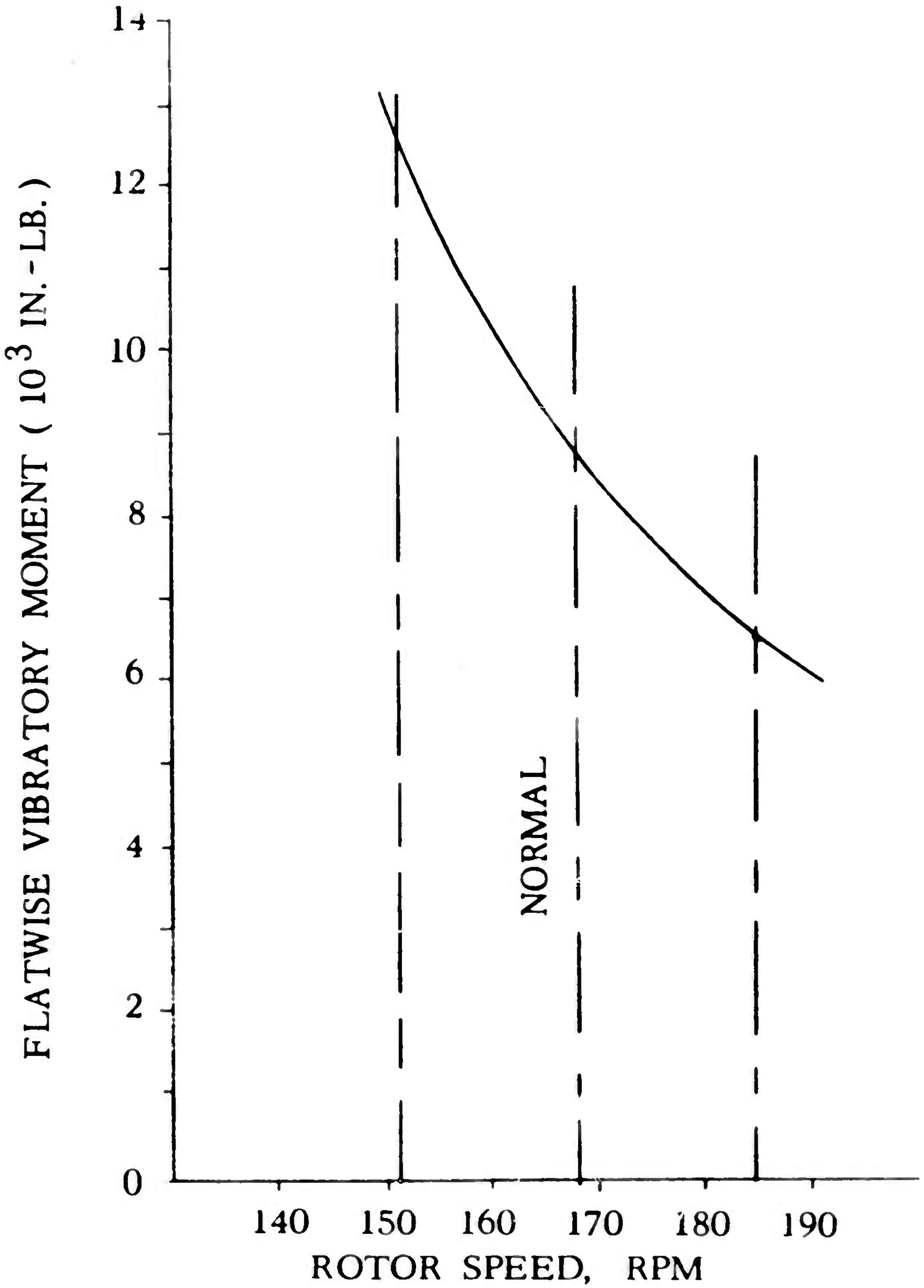


FIG. 8.10 CHANGE IN POWER AND BENDING MOMENT WITH ROTOR SPEED

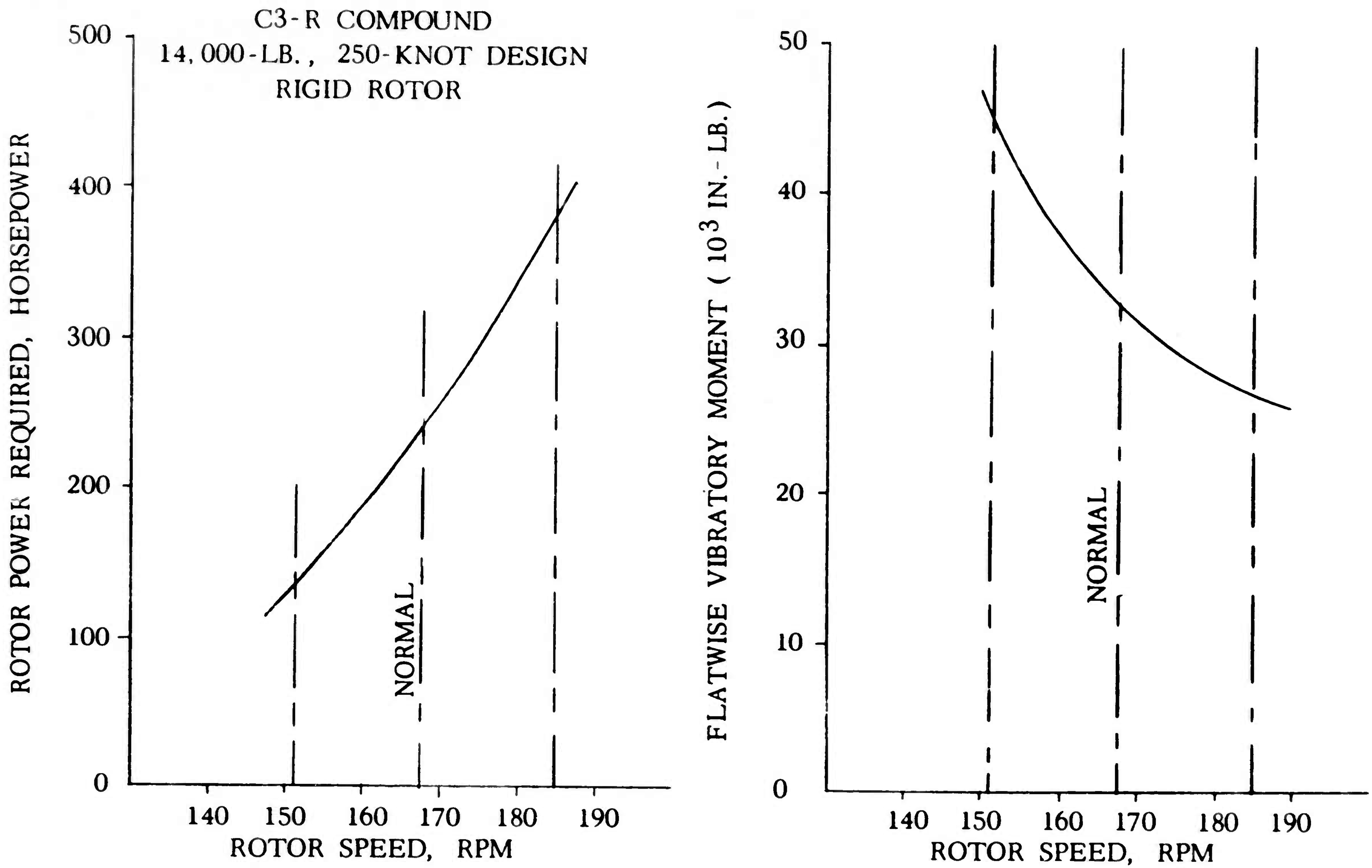


FIG. 8.11 CHANGE IN POWER AND BENDING MOMENT WITH ROTOR SPEED

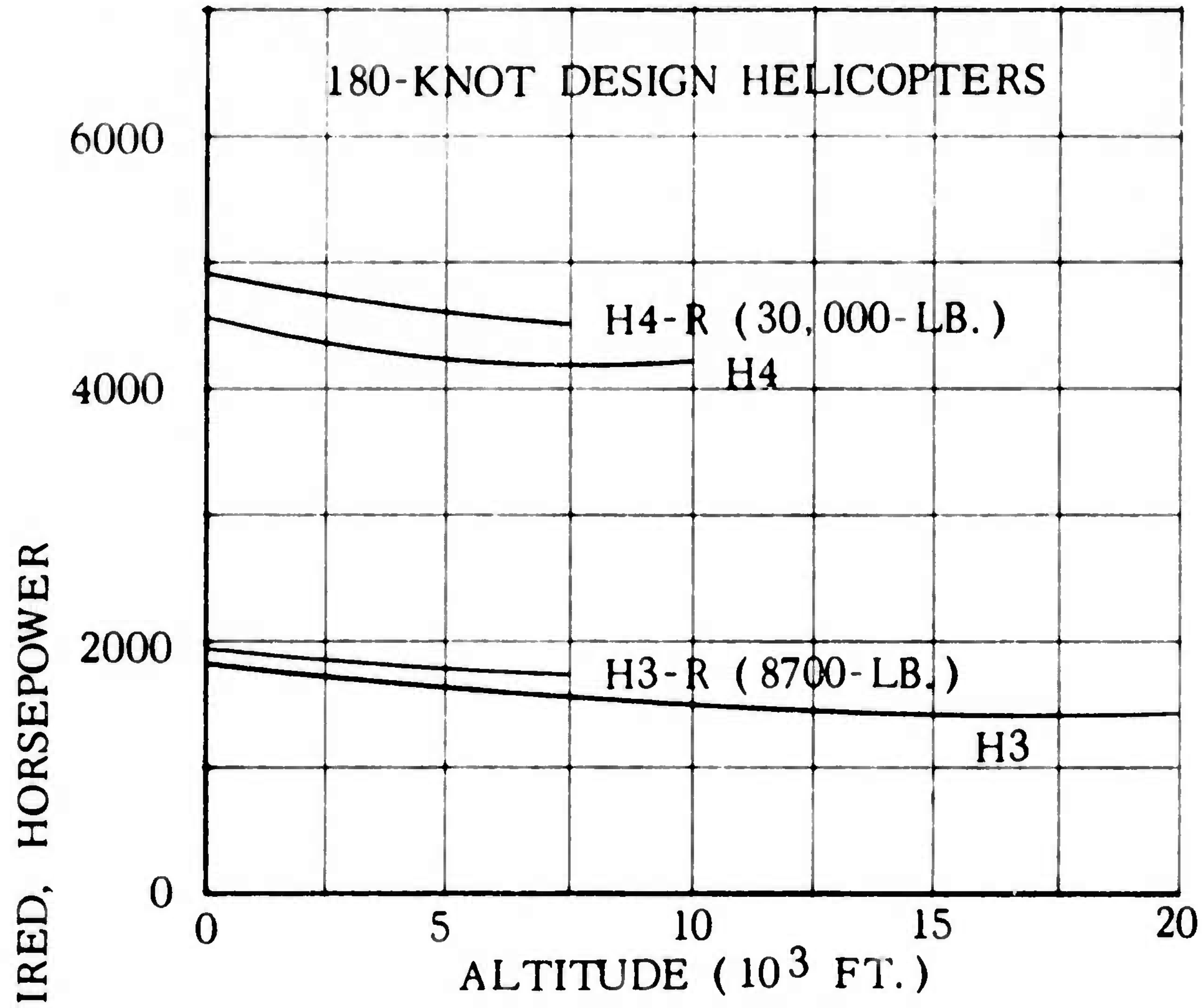


FIG. 8.12 CHANGE IN POWER REQUIRED WITH ALTITUDE, 180 KNOTS

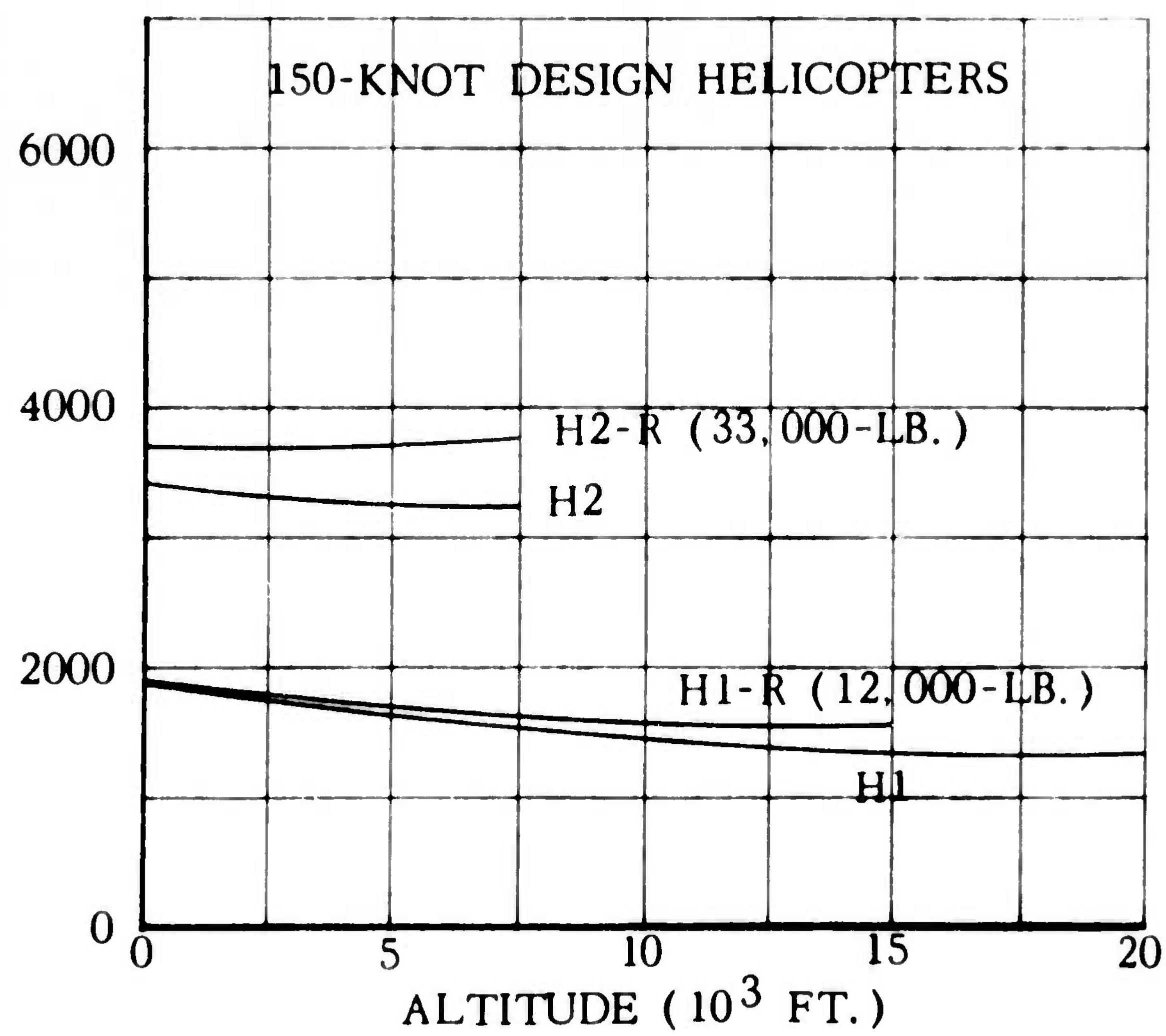


FIG. 8.13 CHANGE IN POWER REQUIRED WITH ALTITUDE, 150 KNOTS

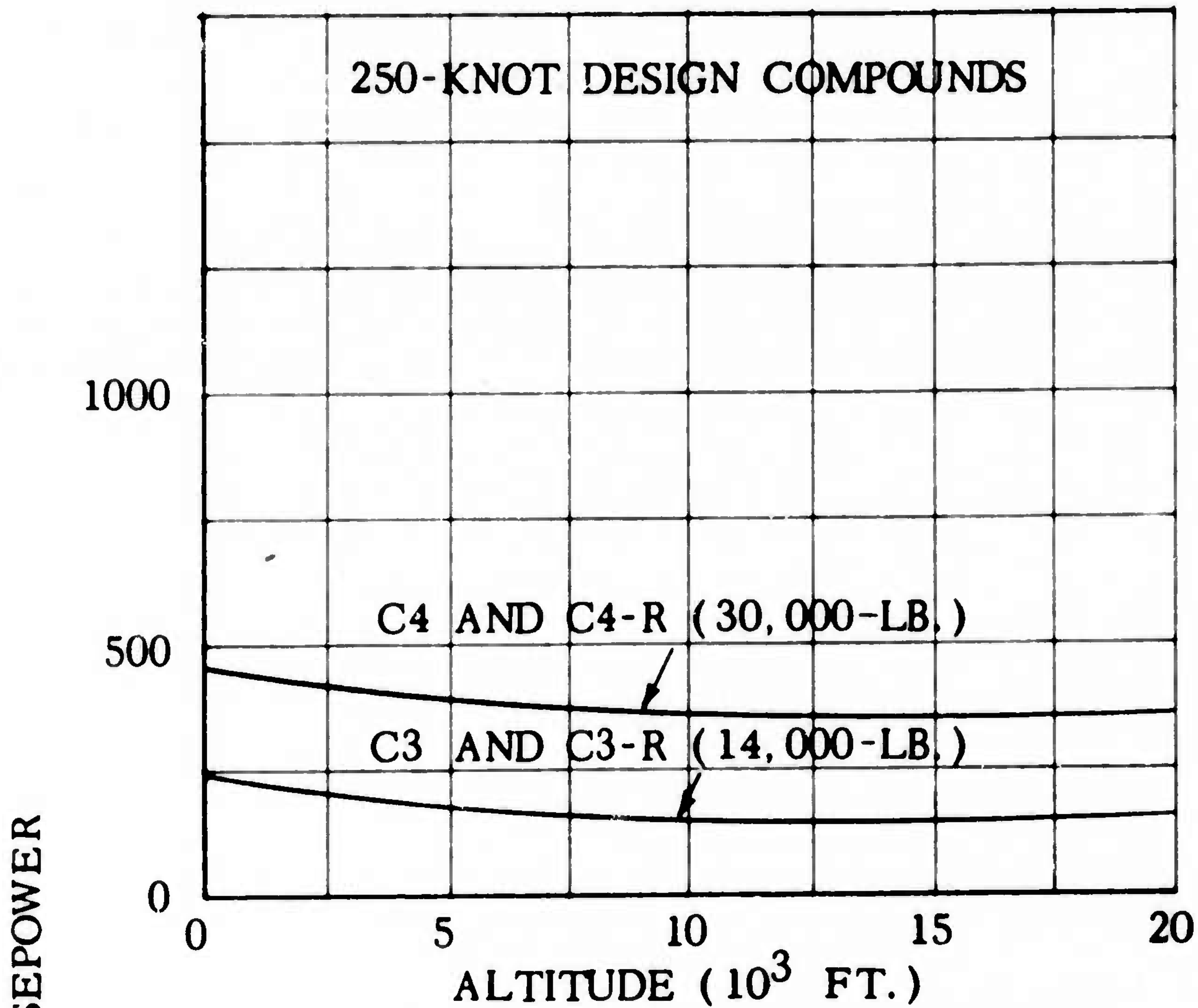


FIG. 8.14 CHANGE IN POWER REQUIRED WITH ALTITUDE, 250 KNOTS

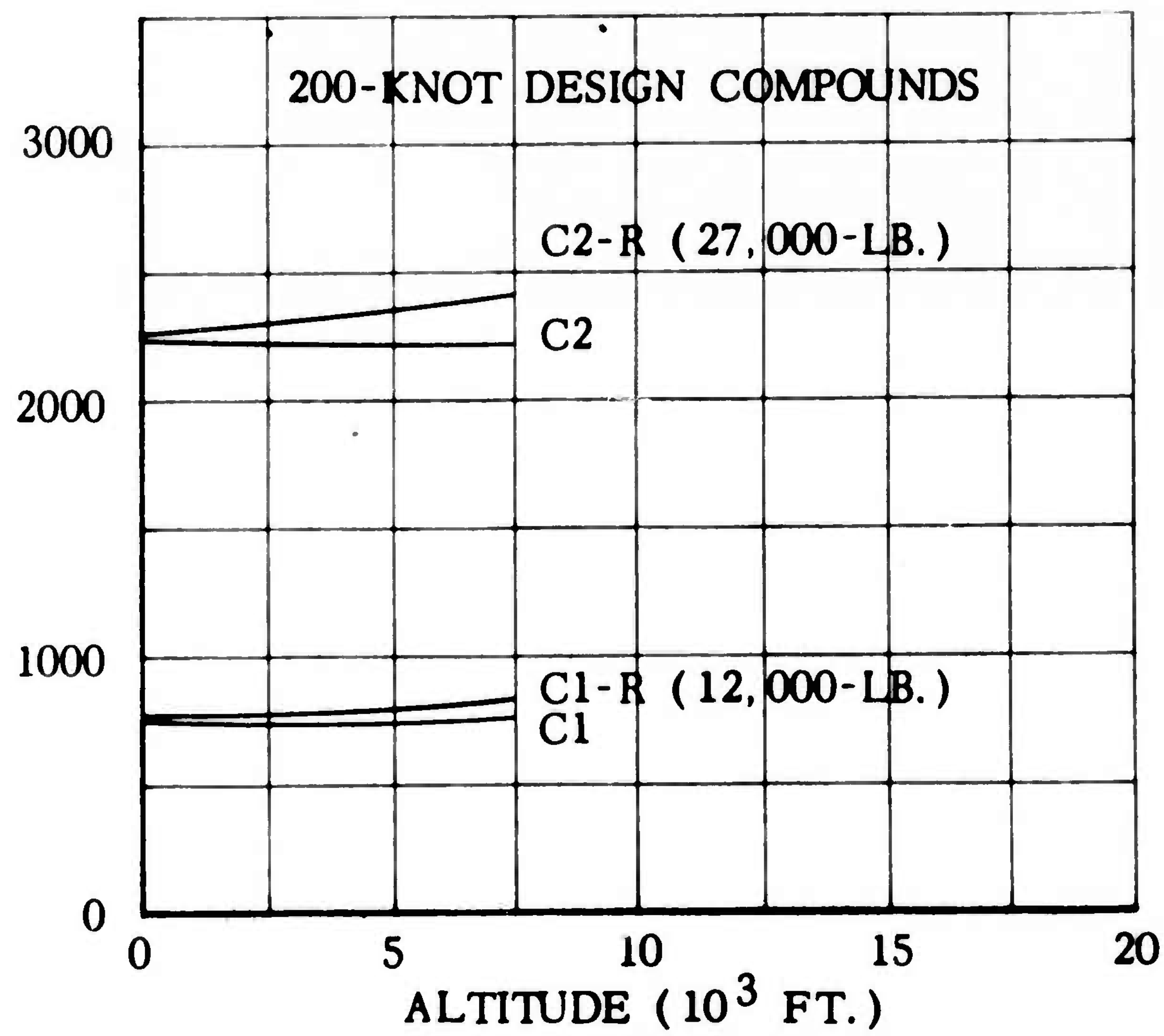


FIG. 8.15 CHANGE IN POWER REQUIRED WITH ALTITUDE, 200-KNOTS

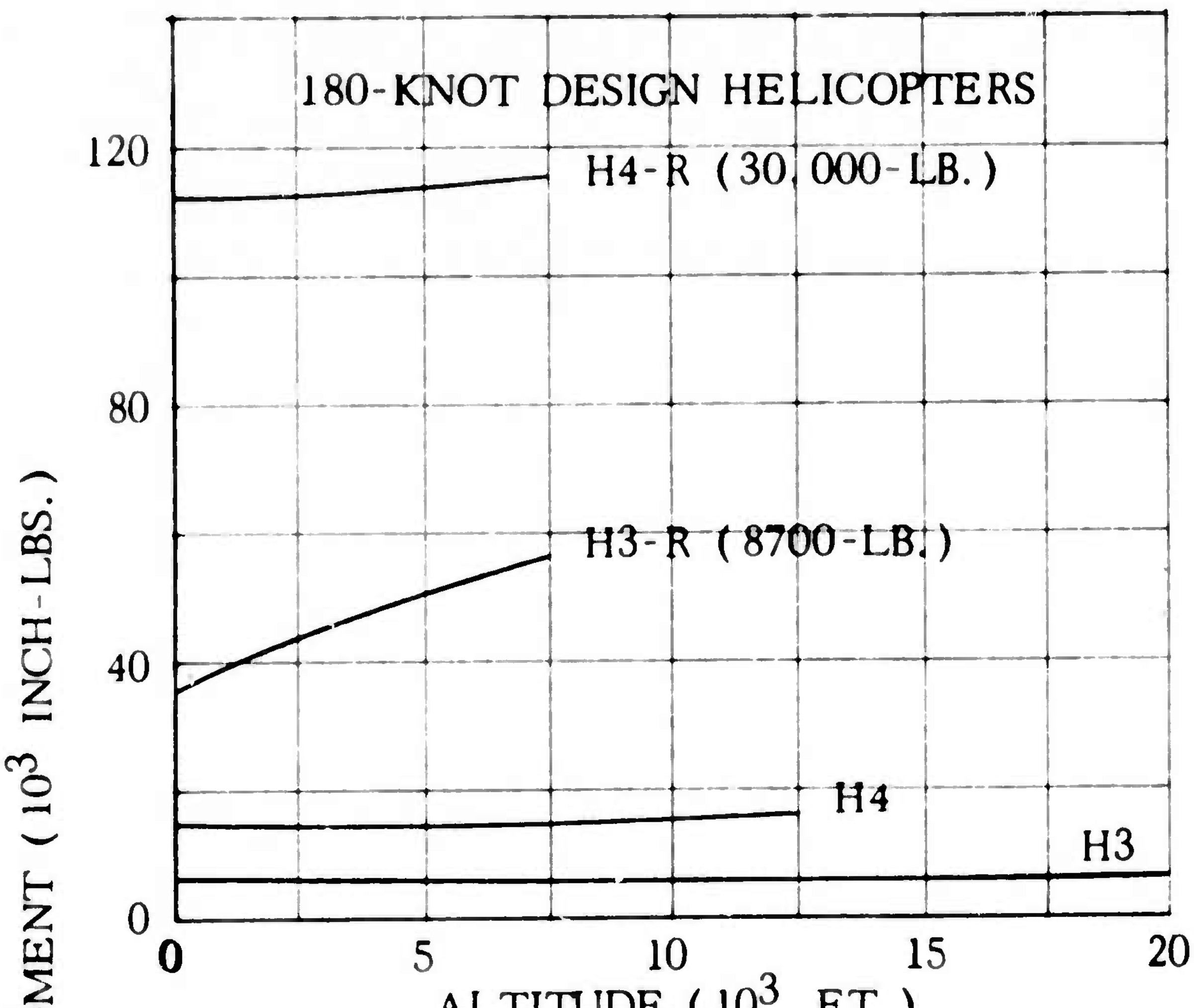


FIG. 8.16 CHANGE IN FLATWISE MOMENT WITH ALTITUDE, 180 KNOTS

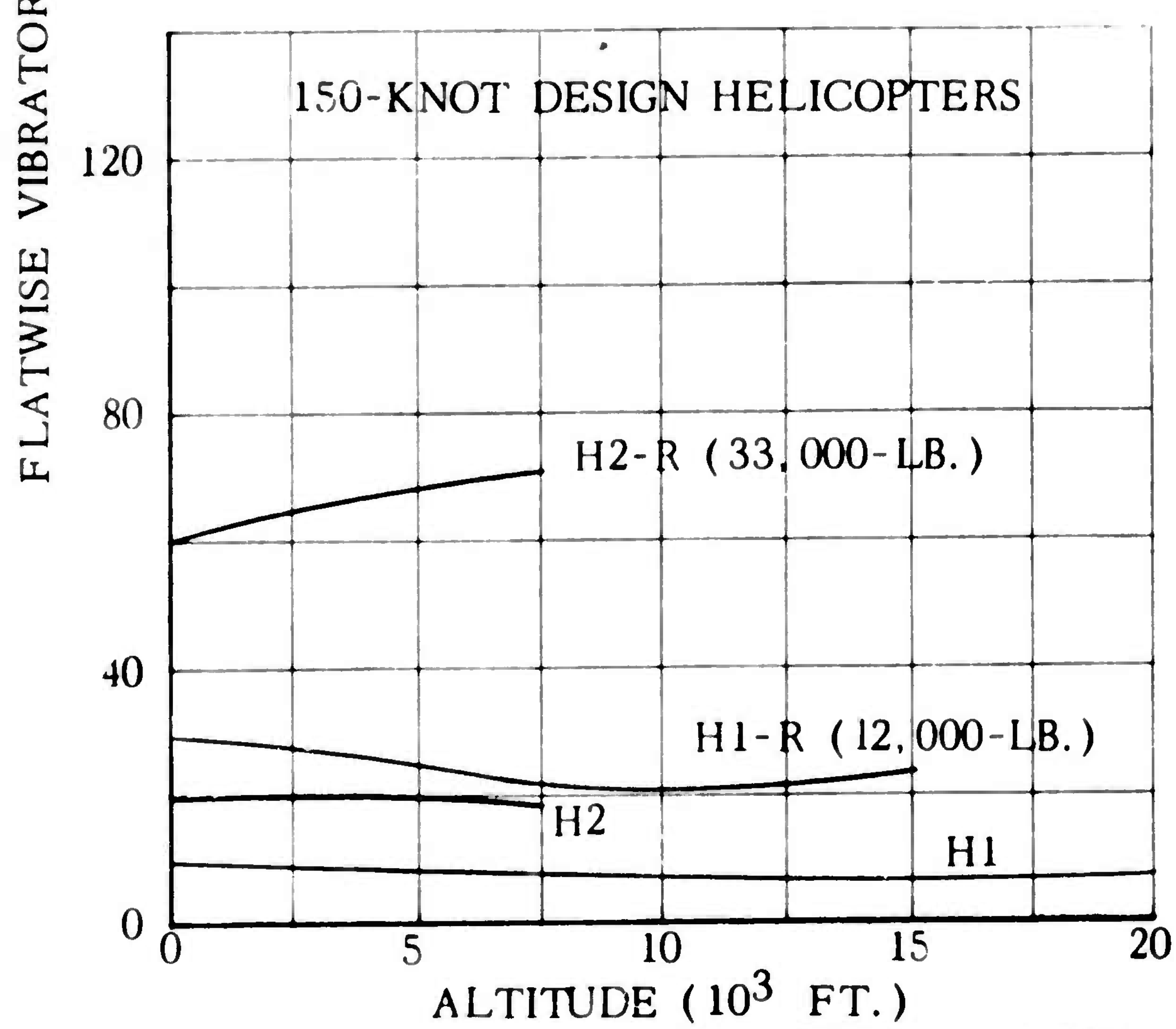


FIG. 8.17 CHANGE IN FLATWISE MOMENT WITH ALTITUDE, 150 KNOTS

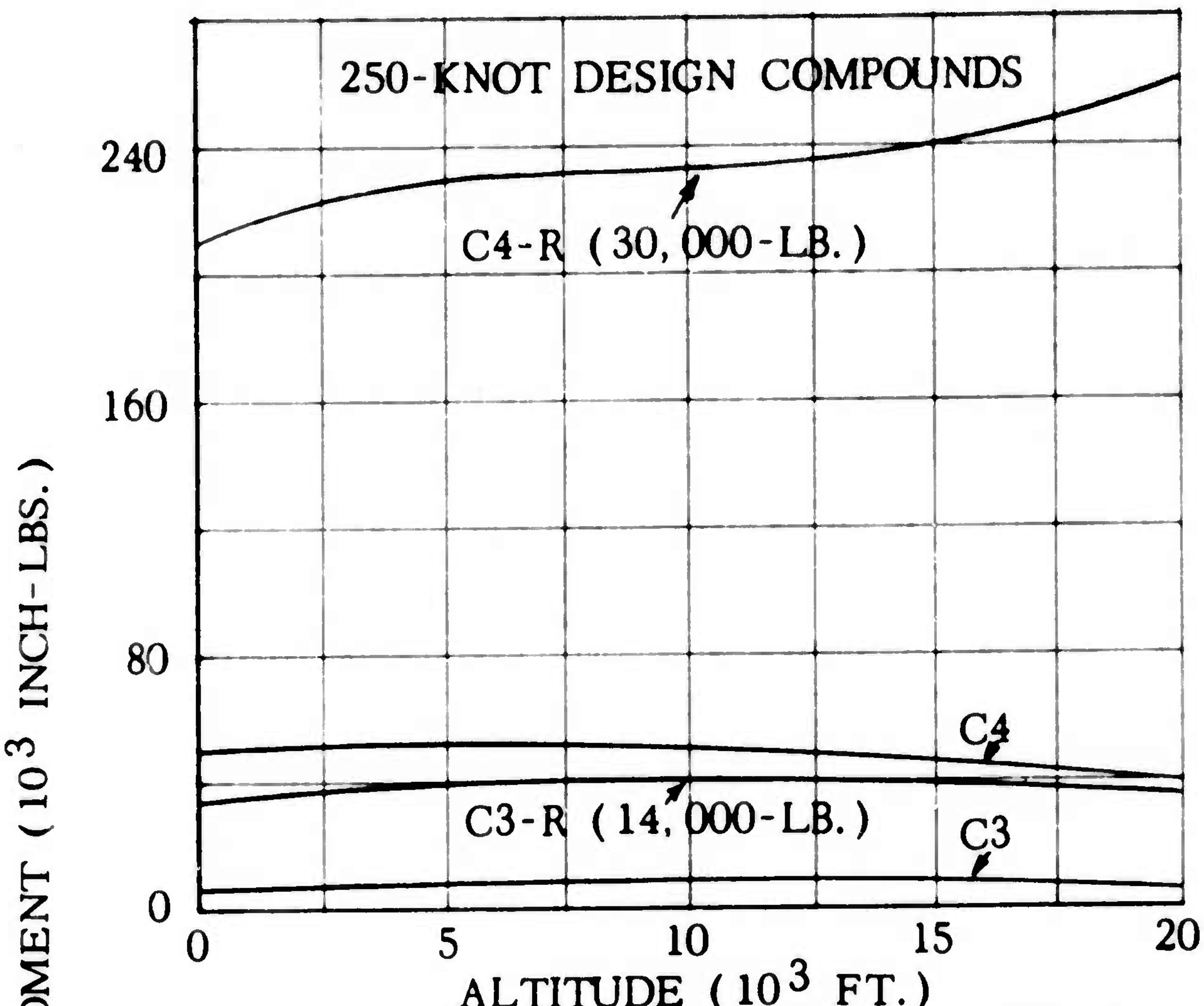


FIG. 8.18 CHANGE IN FLATWISE MOMENT WITH ALTITUDE, 250 KNOTS

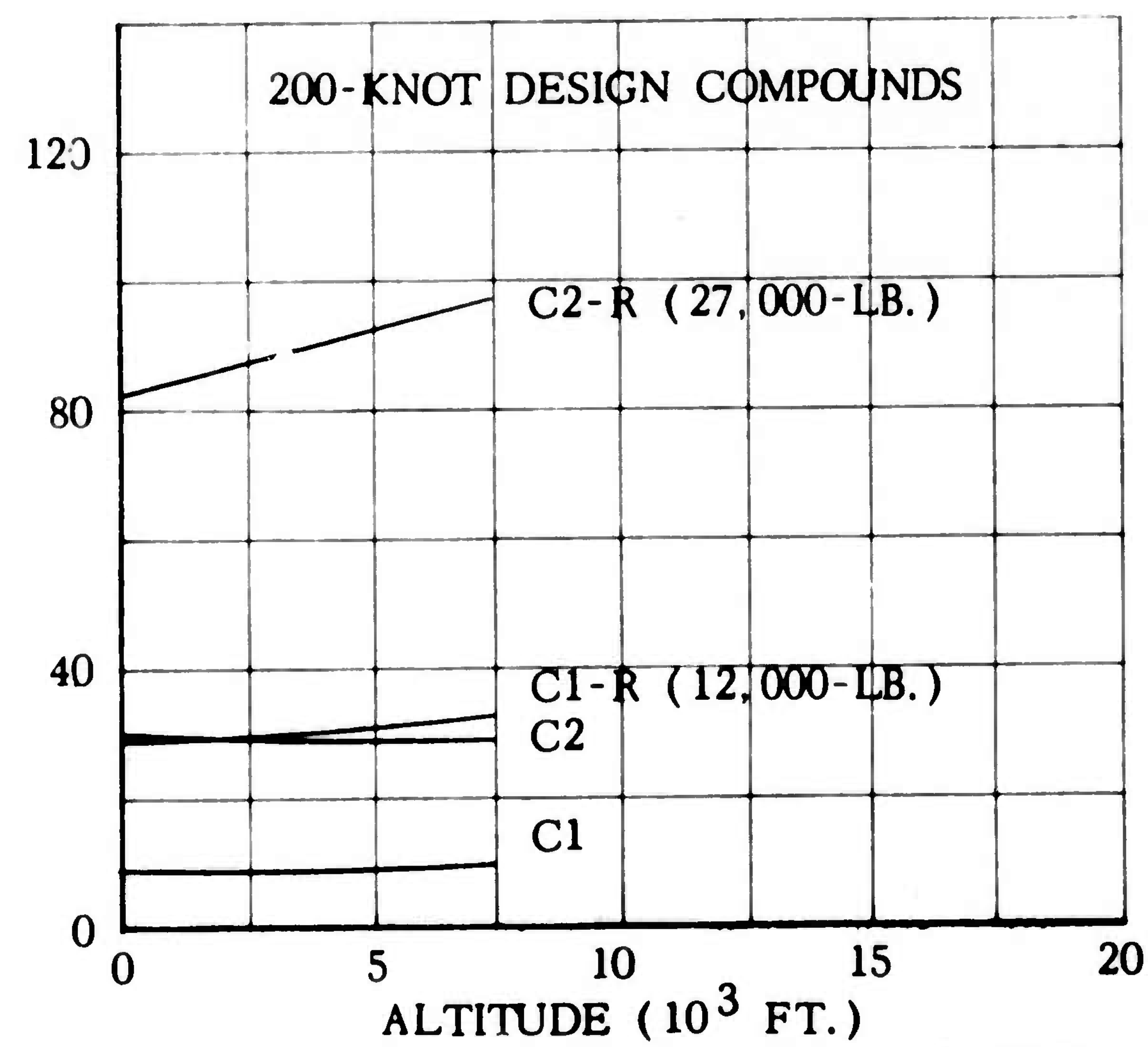


FIG. 8.19 CHANGE IN FLATWISE MOMENT WITH ALTITUDE, 200 KNOTS

9. VARIATION OF BLADE STIFFNESS

Variations in blade stiffness are presented in the schedule given by Table 2. 3. Figures 9. 1 through 9. 4 give results of the study for the 150-knot, 33, 000-pound helicopter. In Figures 9. 1 and 9. 2, flatwise stiffness of the basic blade has been both doubled and reduced by one-half. For the articulated case, the entire moment envelope is seen to increase with increase in stiffness. The same is observed for the rigid blade in the root region. For this case, it is interesting to note that the point of minimum bending moment moves inboard as the blade becomes more flexible. These are typical of the envelopes at each airspeed considered.

Effects of linear variation of stiffness about the basic blade design are given by Figures 9. 3 and 9. 4. Here, flatwise stiffness has been multiplied by factors ranging linearly from 2 at the root to 1/2 at the tip and vice versa. For the articulated blade, the standard design gave lowest vibratory moments as shown by Figure 9. 3. Here, stiffened outboard blade section and softened cuff appear most detrimental. For rigid blades (Figure 9. 4), where the critical region is at the root, the reverse is true. Low root stiffness contributes to lower moments, and the stiffer outboard section does not have a significant detrimental effect.

Figures 9. 5 and 9. 6 show effects of airspeed on maximum flatwise vibratory moments for the stiffness variations just discussed. Results are presented for both rigid and articulated rotor systems. Trends with airspeed are as expected. Increased airspeed results in increased one-per-rev airload dissymmetry. This, in turn, produces increased vibratory moments. Sequence of stiffness variations on a vibratory moment basis did not change with airspeed.

Effects of stiffness distribution on blade vibratory moments can be understood by study of basic beam bending relationships. Vibratory moments can be expressed by:

$$M_{VIB.} = EI\left[\frac{\partial^2 y}{\partial x^2}\right]_{VIB}$$

Or, in terms of the standard blade:

$$\frac{M_{VIB}}{M_{VIB\,STANDARD}} = \frac{I}{I_{STANDARD}} \; \frac{y''}{y''_{STANDARD}}$$

Note that vibratory moment at a blade station is directly proportional to section stiffness and vibratory curvature at that station. Curvature is determined by stiffness, centrifugal loads, and applied aerodynamic plus inertia loads. Azimuth histories of curvature for ratios of I/I_0 1, 2, and 1/2 are shown in Figure 9.7 for the H2 helicopter. Curvature is plotted at the critical blade station. Observe that as I/I_0 increases, there is an associated decrease in vibratory curvature. In other words, the net vibratory moment is a tradeoff between the increase in I and the decrease in curvature. For rotor systems considered here, Figures 9.8 and 9.9 show that section inertia controls this tradeoff. These figures plot moment versus I/I_0 for both articulated and rigid rotor systems. With increased I, an increased moment results for both blades. Also shown are effective I/I_0 values for blades of other stiffness tapers.

Presented in Tables 2.11 and 2.12 is a numerical evaluation of the stiffness-curvature tradeoff for both rigid and articulated systems. For the articulated blade with tapered stiffness, note that the value of I at the critical blade station governs the resulting vibratory moment. Here, both tapered and inverse-tapered blades have the same curvature at the critical station. Yet, vibratory moments are highest for the inverse taper with an increased I of 41% at the critical station.

TABLE 2.11
EVALUATION OF BLADE STIFFNESS CURVATURE TRADEOFF - ARTICULATED ROTOR

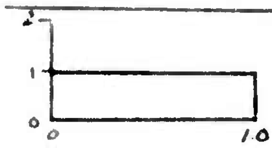
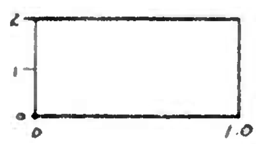
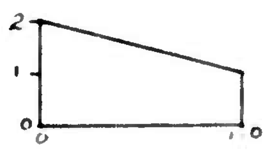
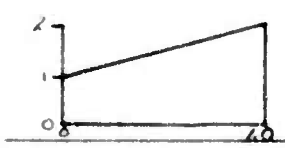
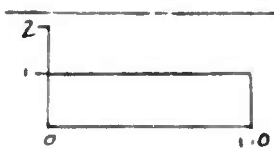
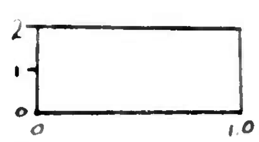
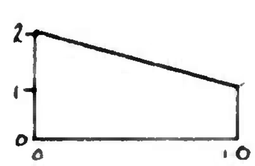
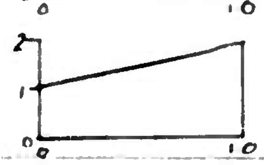
Case	M_v	I_{crit}	I / I_{st}	M_v / M_{vst}	y'' / y''_{st}
	19939.	5.80	1.0	1.0	1.0
	32451.	11.60	2.0	1.62	.810
	12272.	2.90	.5	.615	1.23
	22000	7.26	1.25	1.10	.88
	24913	8.20	1.41	1.25	.886

TABLE 2.12
EVALUATION OF BLADE STIFFNESS CURVATURE TRADEOFF - RIGID ROTOR

Case	M_v	I_{crit}	I / I_{st}	M_v / M_{vst}	$\ddot{y} / \ddot{y}_{st}$
	61000	10.00	1.0	1.0	1.0
	86500	20.00	2.0	1.415	.7075
	40500	5.00	.5	.665	1.330
	82570	20.00	2.0	1.35	.675
	47000	5.00	.5	.77	1.54

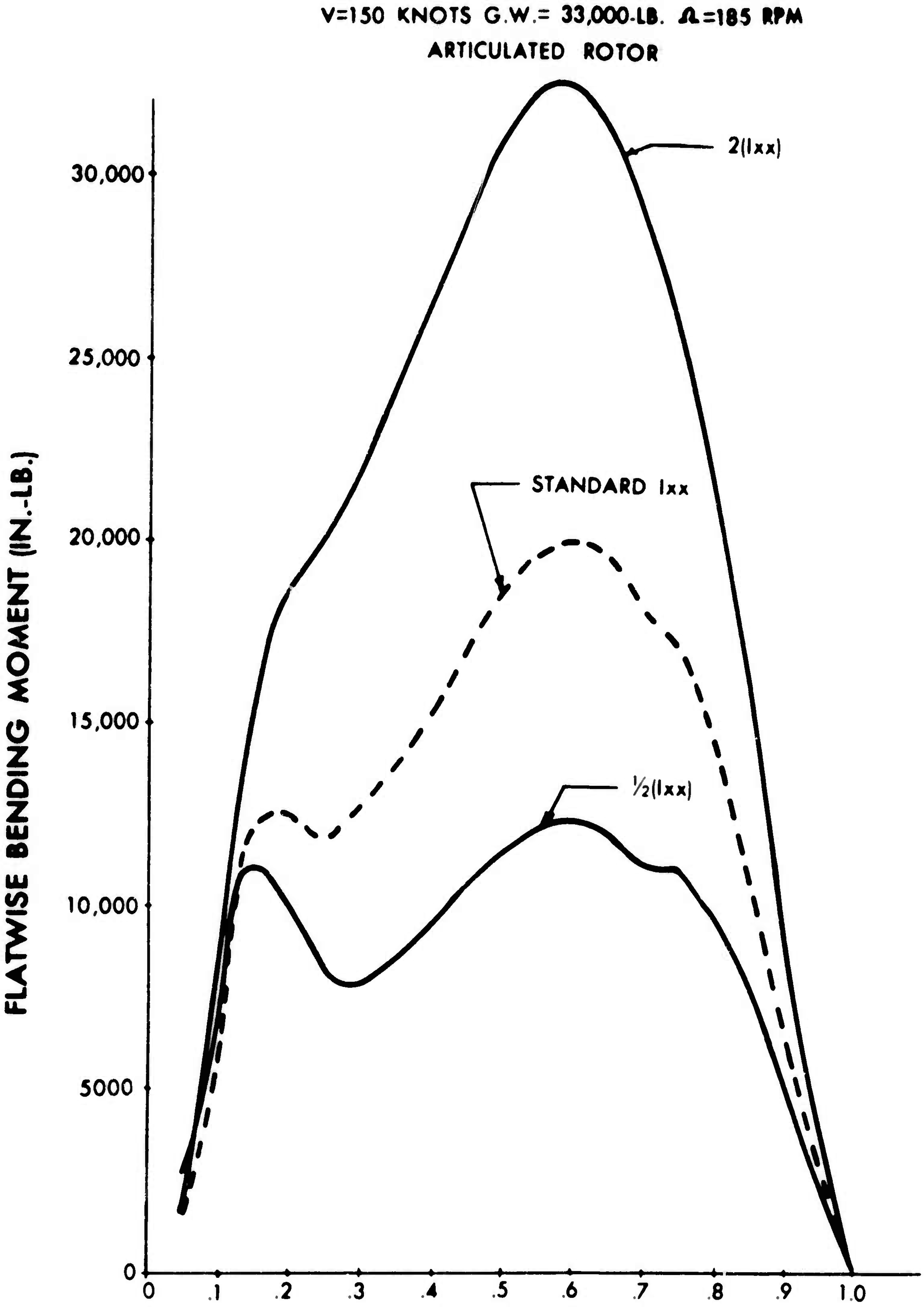


FIGURE 9.1 EFFECT OF VARIABLE FLATWISE STIFFNESS ON BENDING MOMENT

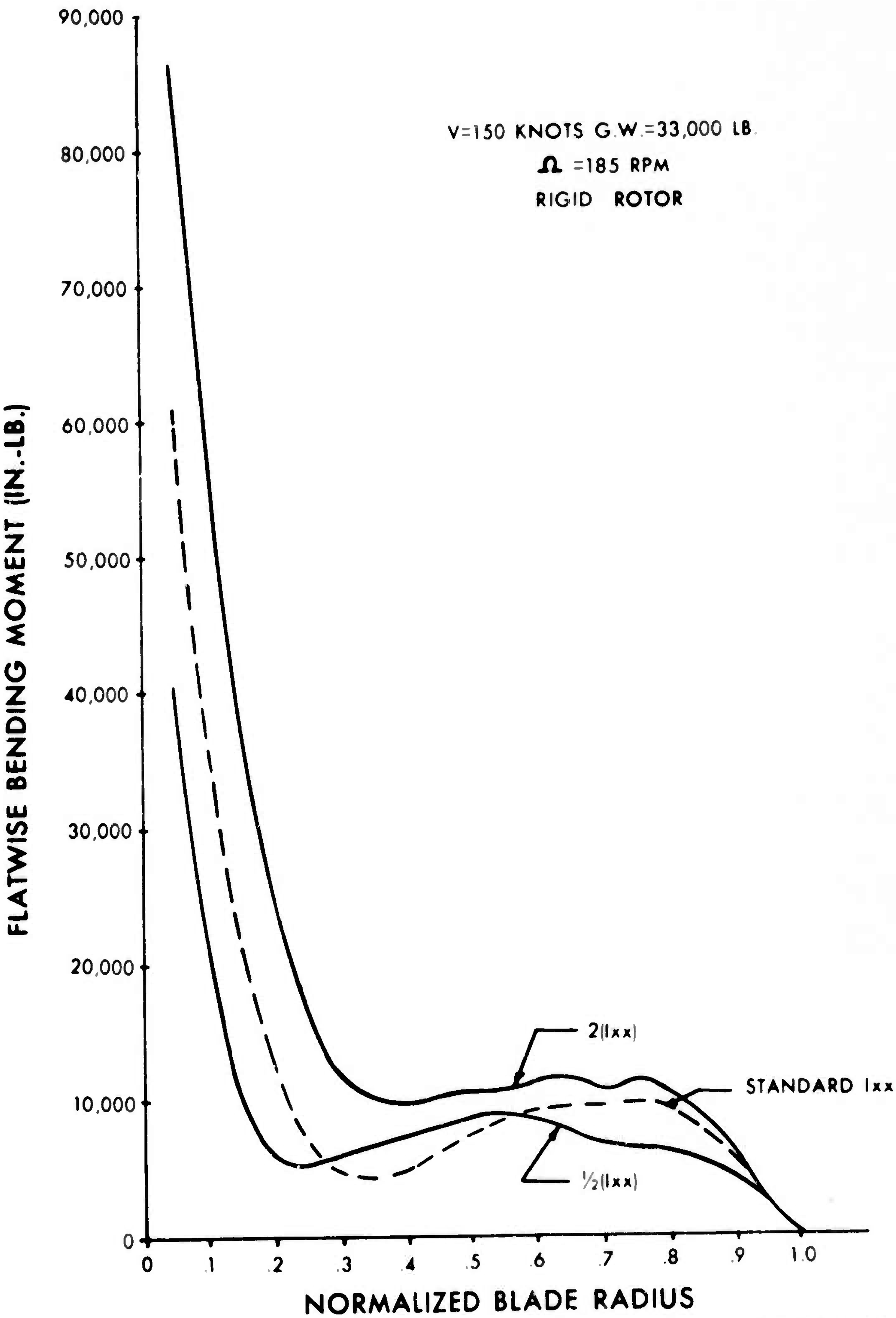


FIGURE 9.2 EFFECT OF VARIABLE FLATWISE STIFFNESS ON BENDING MOMENT

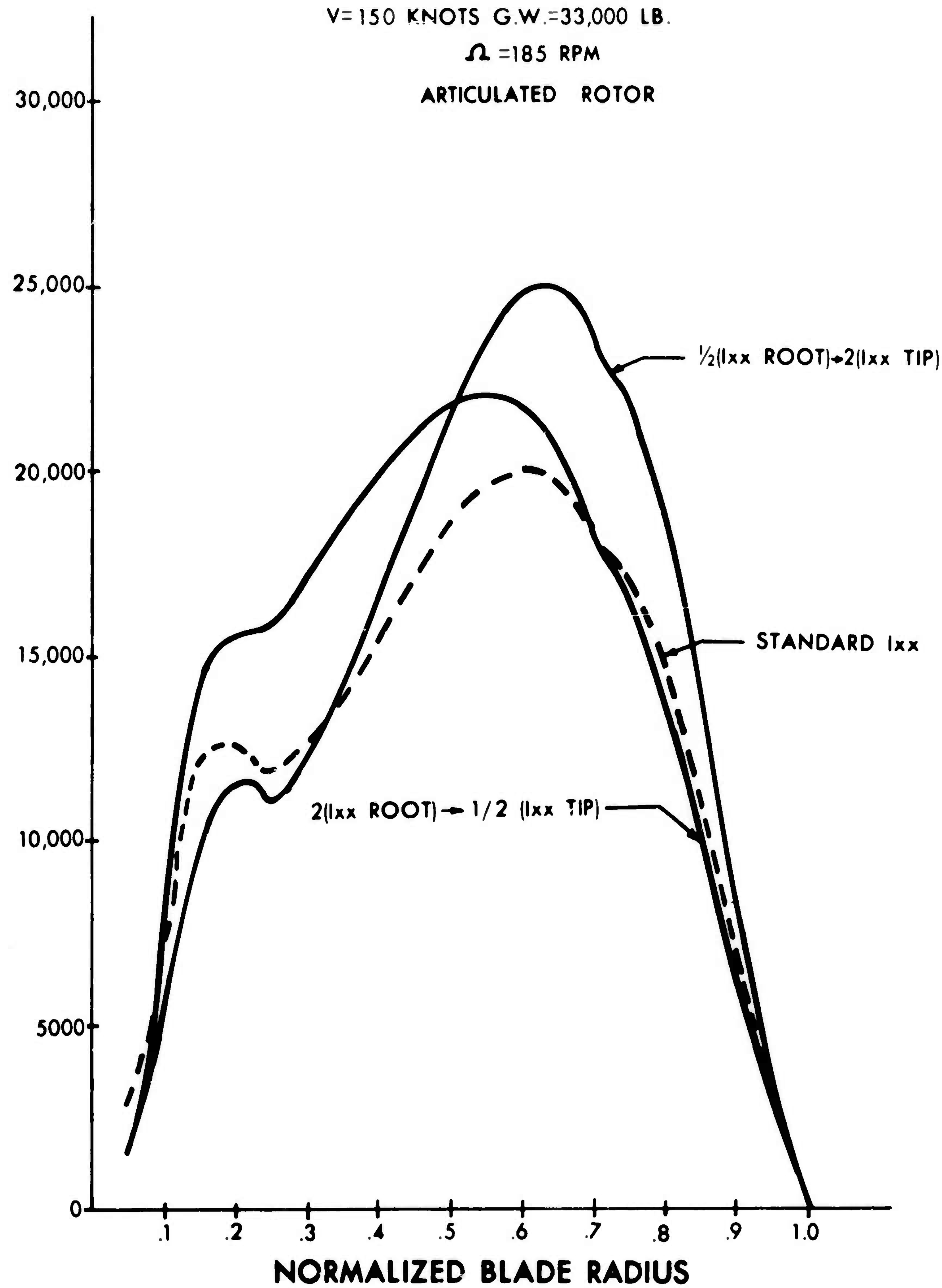


FIGURE 9.3 EFFECT OF VARIABLE FLATWISE STIFFNESS ON BENDING MOMENT

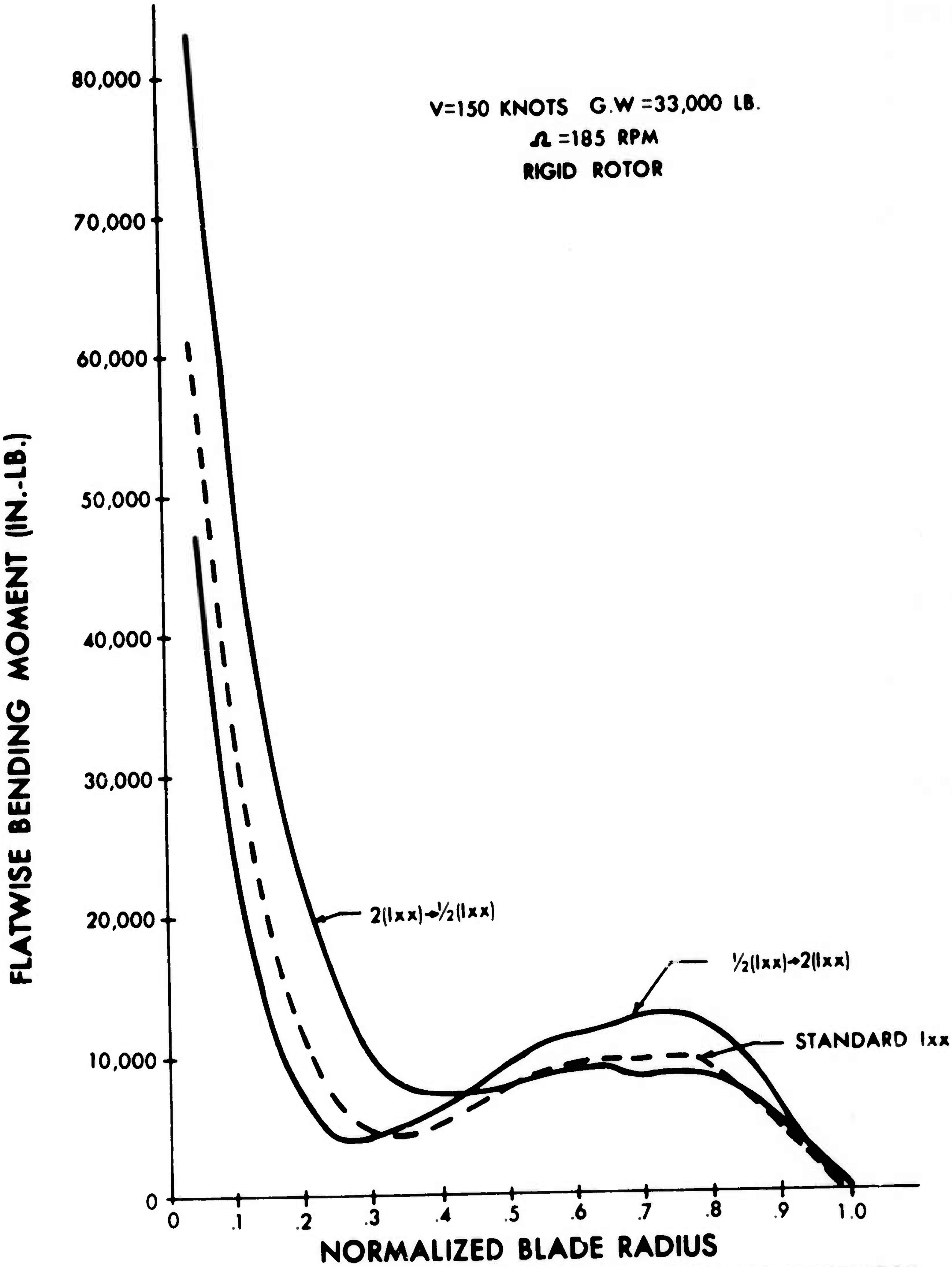


FIGURE 9.4 EFFECT OF VARIABLE FLATWISE STIFFNESS ON BENDING MOMENT

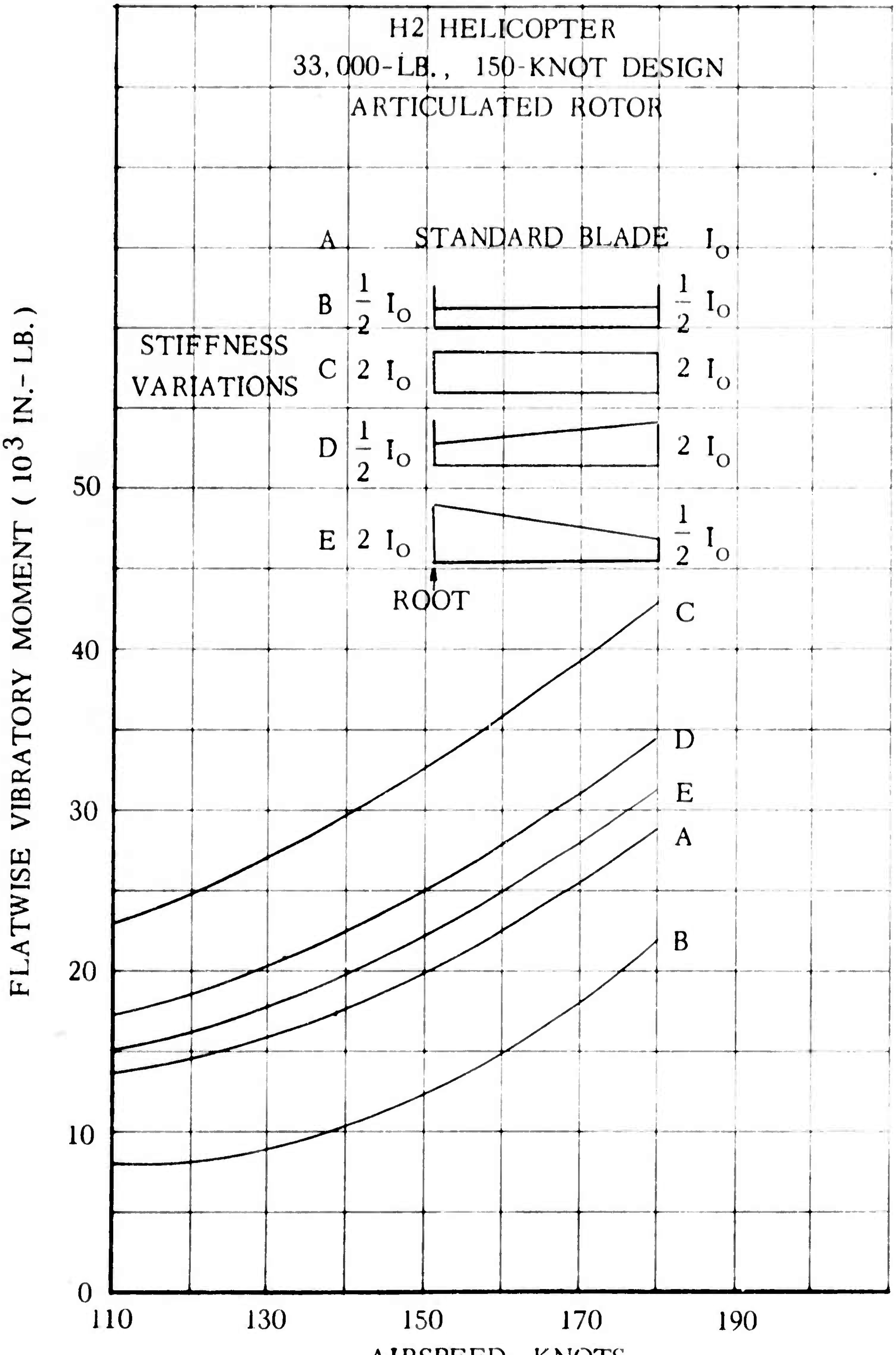


FIG. 9.5 CHANGE IN BENDING MOMENT WITH STIFFNESS VARIATION

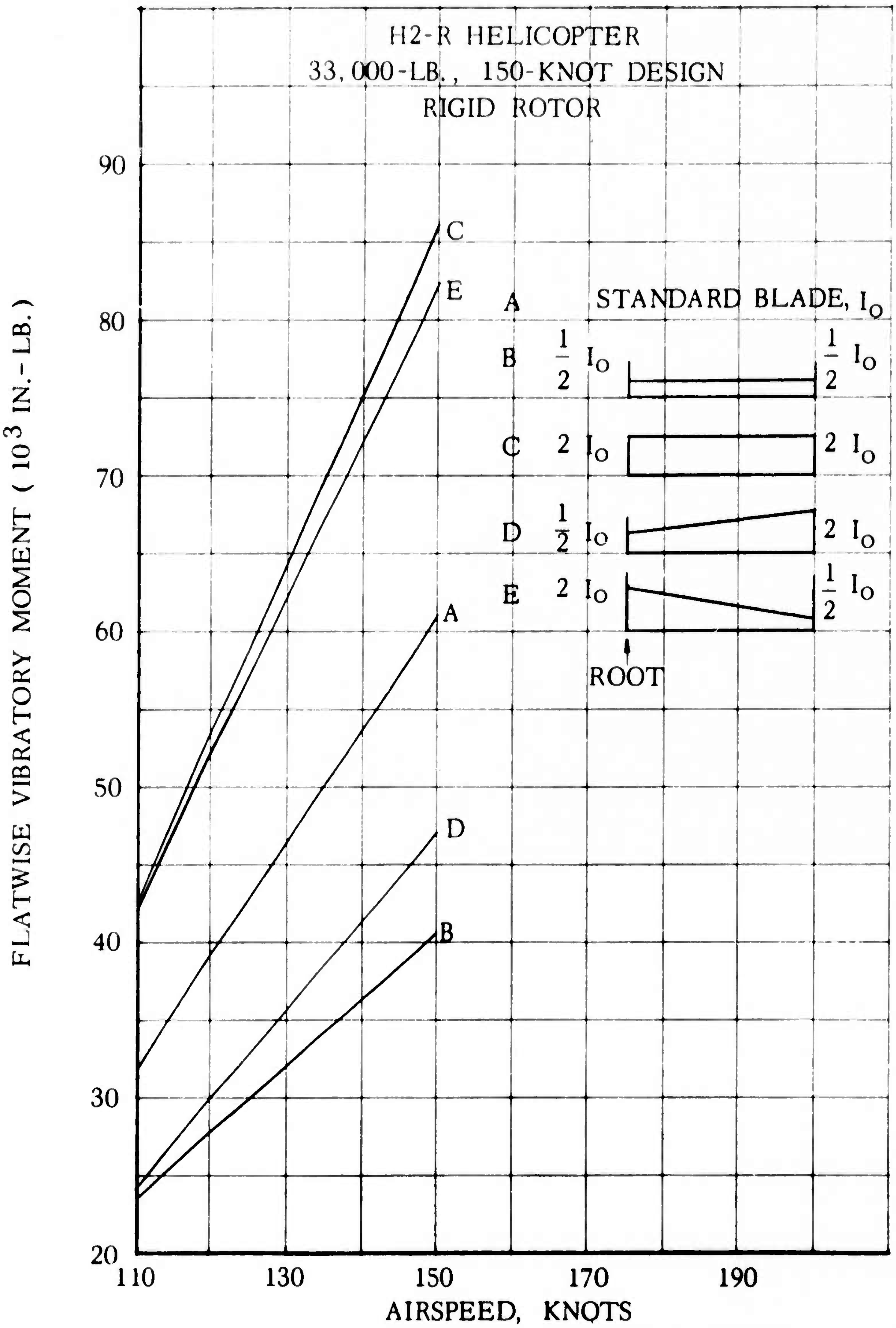


FIG. 9.6 CHANGE IN BENDING MOMENT WITH STIFFNESS VARIATION

H2 HELICOPTER
33,000-LB., 150 KNOTS
ARTICULATED ROTOR

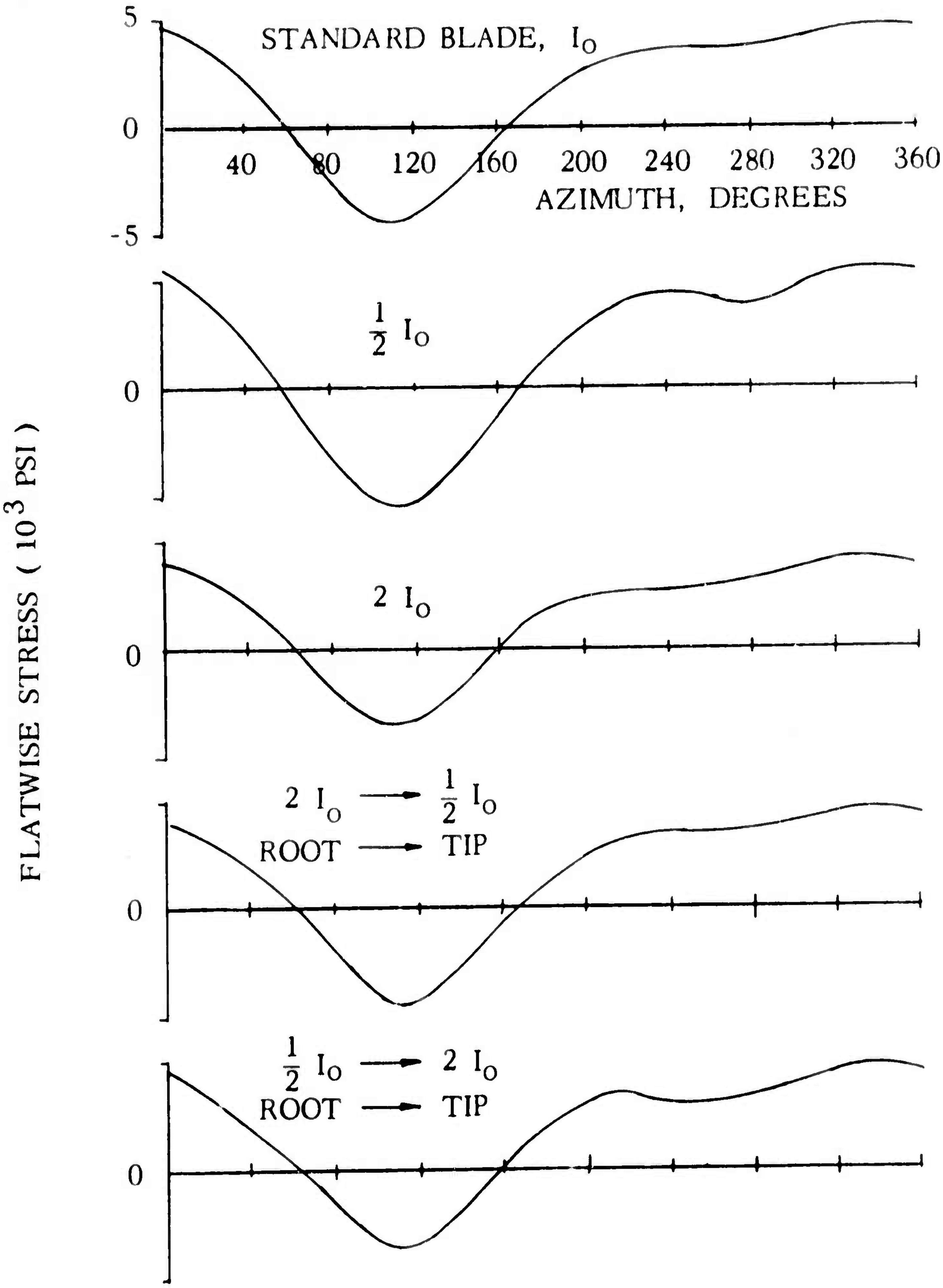


FIG. 9.7 CHANGE IN FLATWISE STRESS WITH AZIMUTH FOR FIVE STIFFNESS VARIATIONS

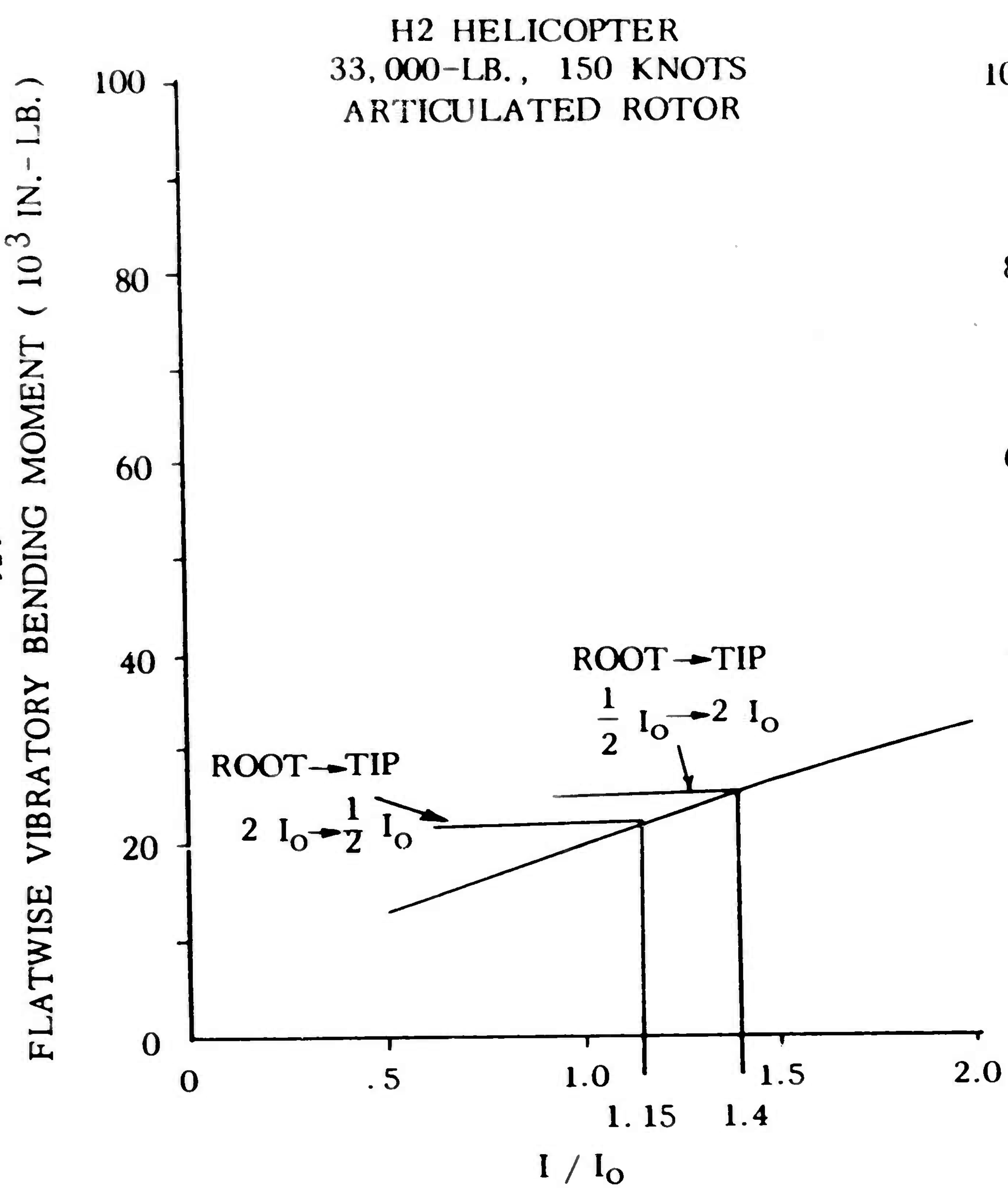


FIG. 9.8 CHANGE IN BENDING MOMENT WITH STIFFNESS

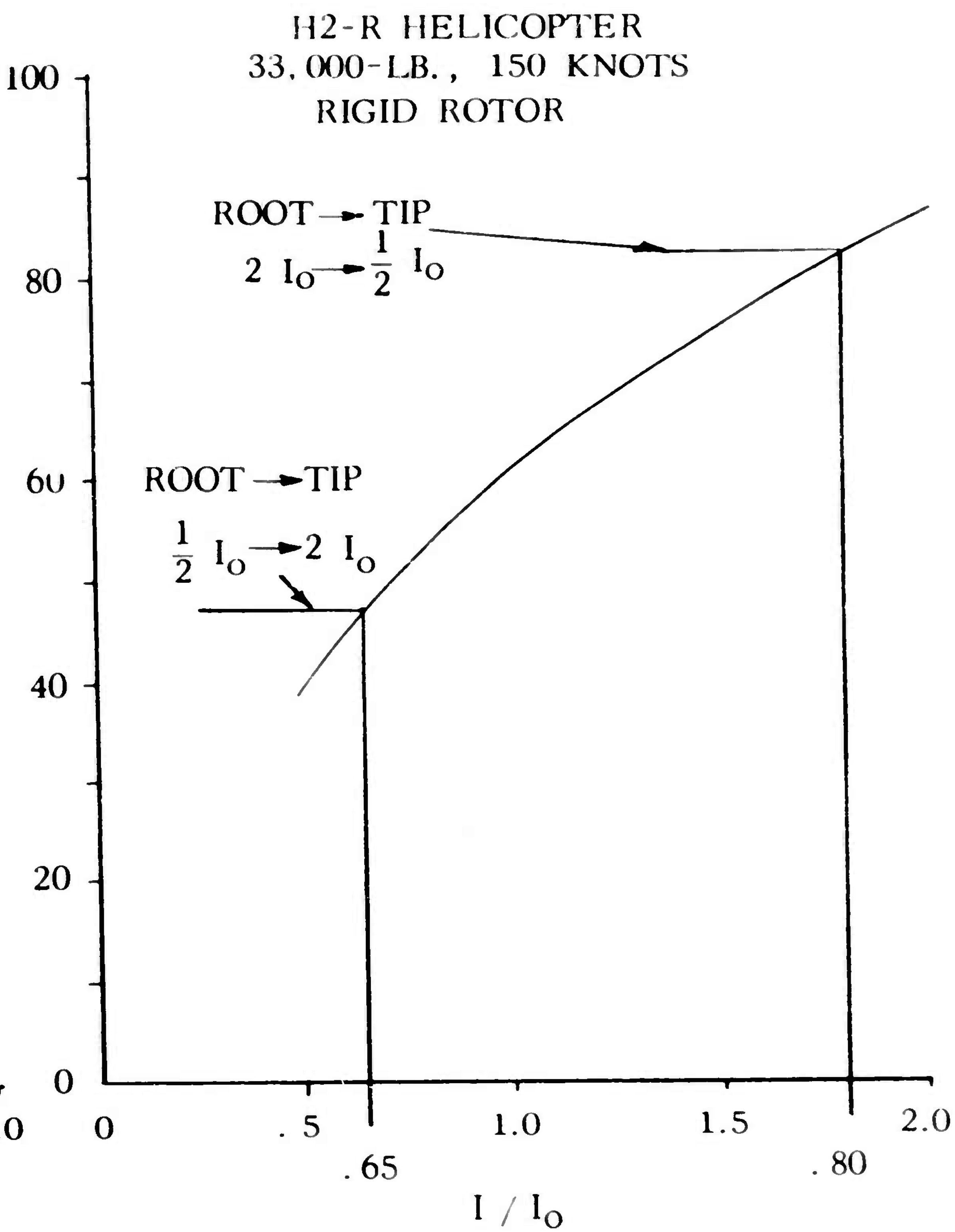


FIG. 9.9 CHANGE IN BENDING MOMENT WITH STIFFNESS

10. BLADE MASS DISTRIBUTION

Studies of changes in blade mass distribution were carried out according to the schedule shown in Table 2. 4. Given in Figures 10. 1 and 10. 2 are effects on flatwise vibratory moments for the 33, 000-pound helicopter by separately introducing a concentrated 36-pound weight at five radial locations along the blade. Radial moment envelopes for the five positions for an articulated blade are presented in Figure 10. 1. The standard unweighted blade (not shown) had a maximum vibratory moment of 20, 000 in. -lb. Given in Figure 10. 3 is a plot of maximum vibratory moment versus blade weight location. Results indicate (1) a significant reduction in vibratory moments (34%) by introducing a weight at the blade tip, and (2) an increase in vibratory moment (max. 38% with weight at r/R = . 63) by locating a concentrated weight inboard of 90% radius. Effect on flatwise and edgewise maximum moments by varying the amount of weight added to the blade tip is given by curves shown to the right of Figure 10. 4. Here, vibratory moment reduction is greatest with the first 10 pounds added; it then levels off in the 30-to-40-pound region.

Effects of added concentrated weights for rigid blade moments are plotted in Figure 10.2. In this case the root region was most critical. Maximum vibratory moment for the standard blade (not shown) was 61, 000 in. -lb. Figure 10. 5 shows the trend in maximum vibratory moment with change in location of the concentrated weight. Here, the tip weight again produced a significant reduction (25%), but weights inboard resulted in an increase (max. of 15% with weight at r/R = . 40). The left-hand plots of Figure 10. 4 present results of varying tip weight on rigid blade moments. Flatwise moment reduction follows the same trend as the articulated system. The sharp continuous reduction shown for edgewise moments is attributed to detuning the first edgewise mode. The rigid blade in this case (aspect ratio = 18) was designed for $\omega_1^E = .65\,\Omega$. Added weight brings this mode further below one-per-rev. Were a stiff inplane design used, the addition of tip weight would have the opposite effect. Edgewise moments would increase, for the first edgewise mode would be reduced from $1.4\,\Omega$ in the direction of one-per-rev.

Radial moment envelopes for various single weight locations for a six-bladed teetering rotor are given in Figure 10. 6. For this rotor system, results show moment increases at all points of location of concentrated weight.

Effects of various combinations of two 18-pound weights are shown in Figures 10.8, 10.9, and 10.10 for articulated, rigid, and six-blade teetering rotors respectively. Lowest moments were noted for the combination that included a concentrated tip weight with the second weight well inboard where single weight studies showed only a small moment increase.

Shown by Figures 10.11, 10.12, and 10.13 are results from tapering blade mass distribution for the three rotor systems as specified by Table 2.4. Increasing mass with rotor radius was found to reduce blade vibratory moments, whereas decreasing mass with rotor radius gave increased vibratory moments. Similar to the findings with concentrated weights, these results show reduced moments as weight is added at the blade tip.

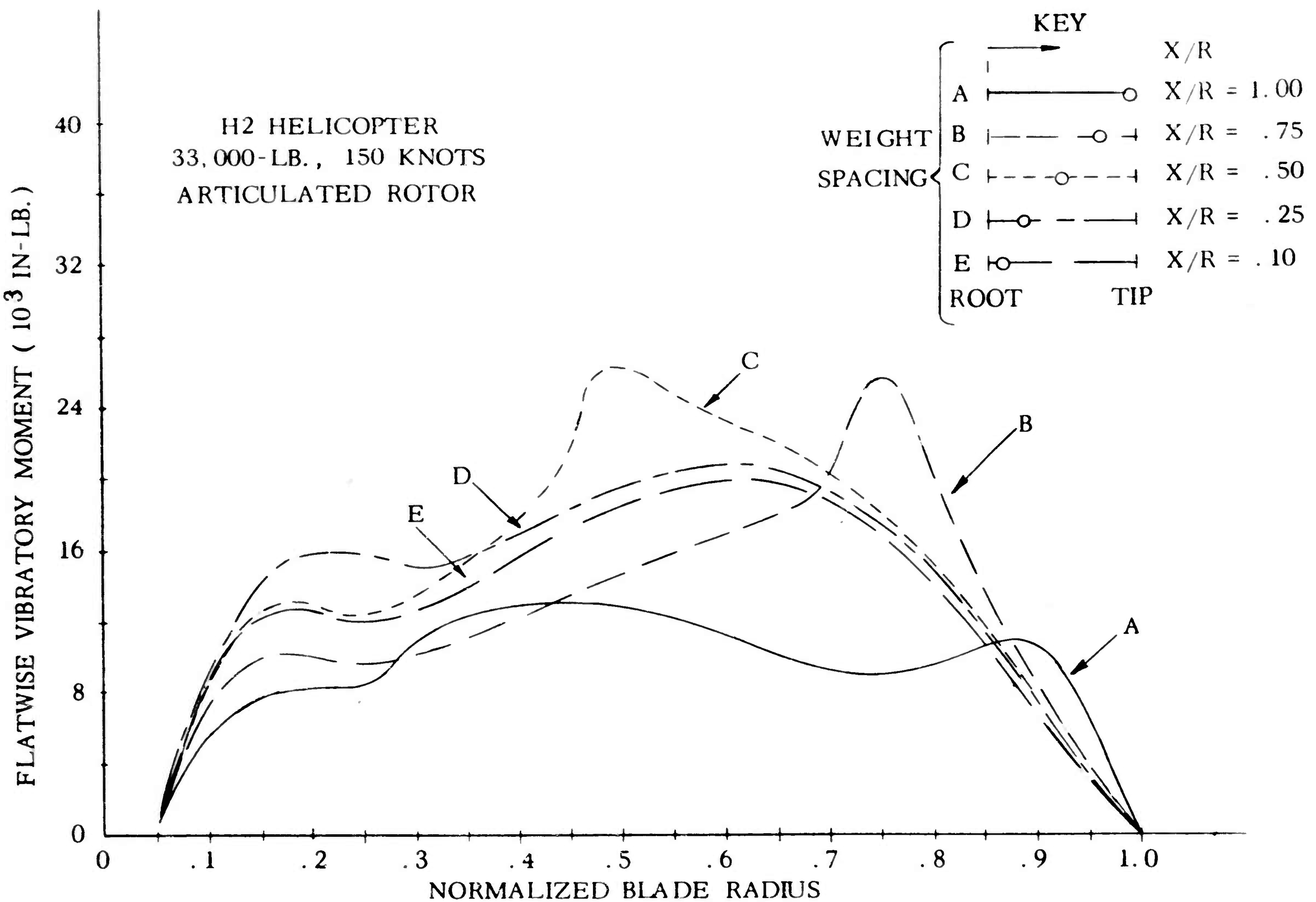


FIG. 10.1 EFFECT OF SINGLE 36-LB. WEIGHT ON FLATWISE MOMENT

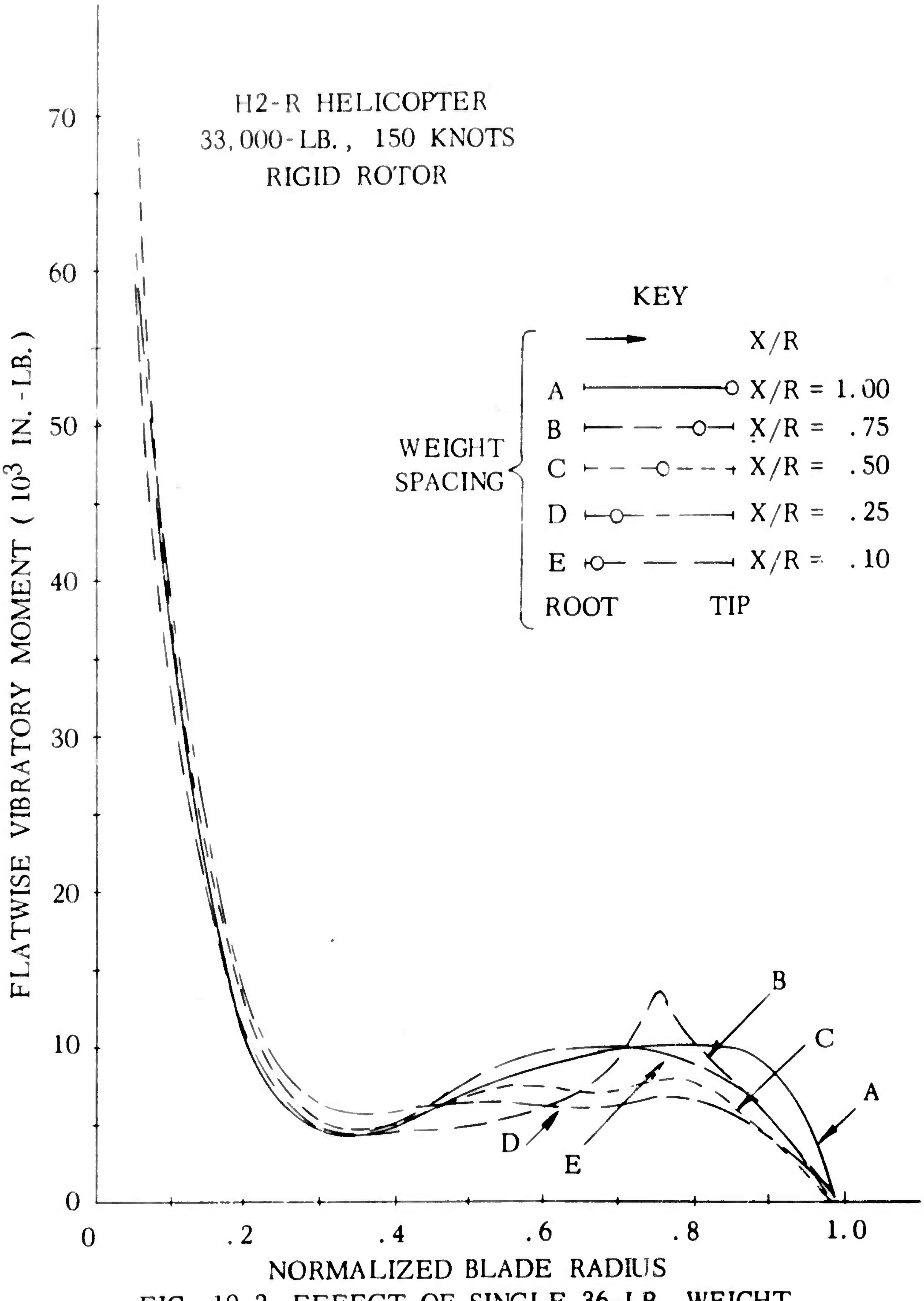


FIG. 10.2 EFFECT OF SINGLE 36-LB. WEIGHT ON FLATWISE MOMENT

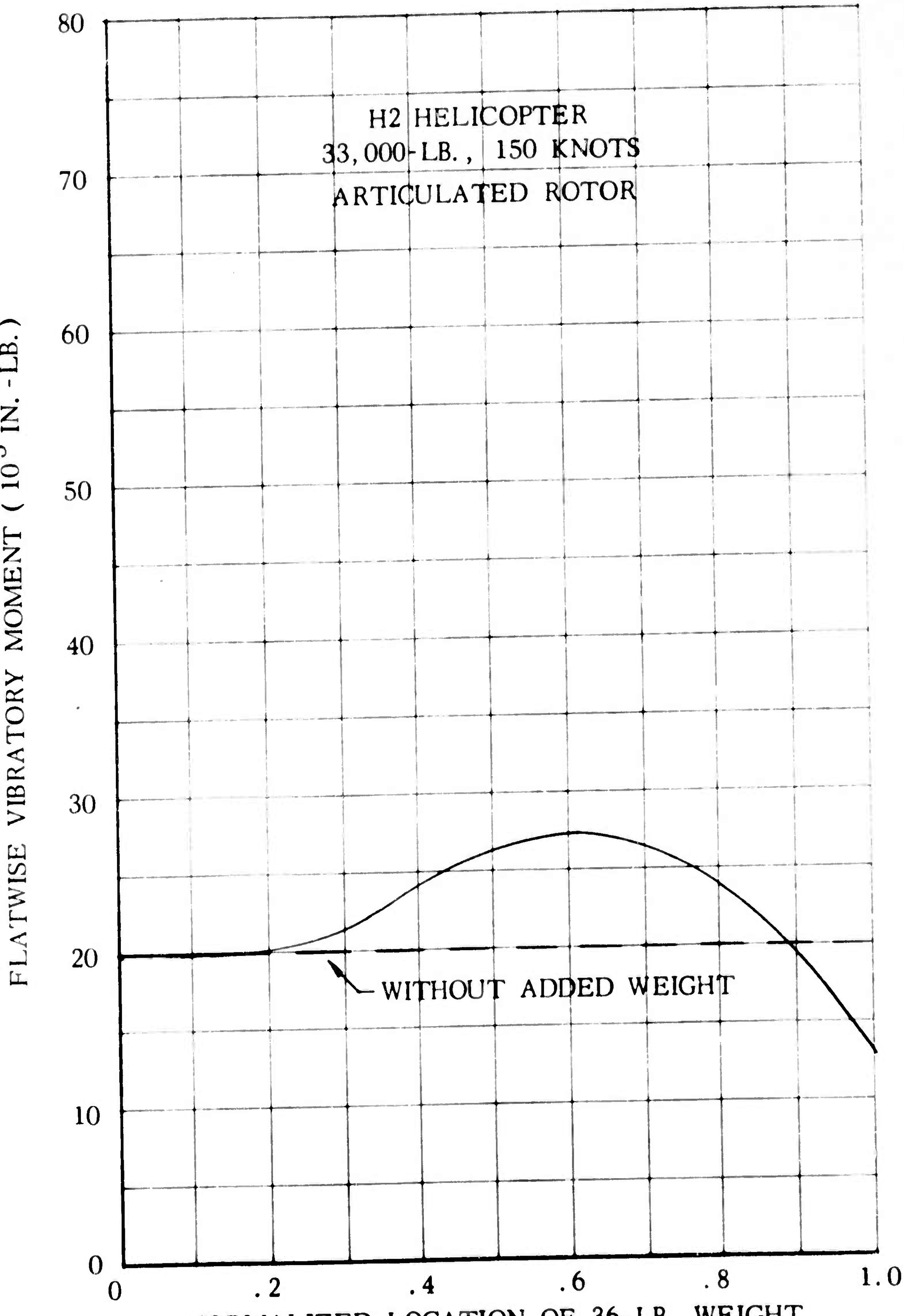


FIG. 10.3 CHANGE IN VIBRATORY MOMENT WITH LOCATION OF ADDED WEIGHT

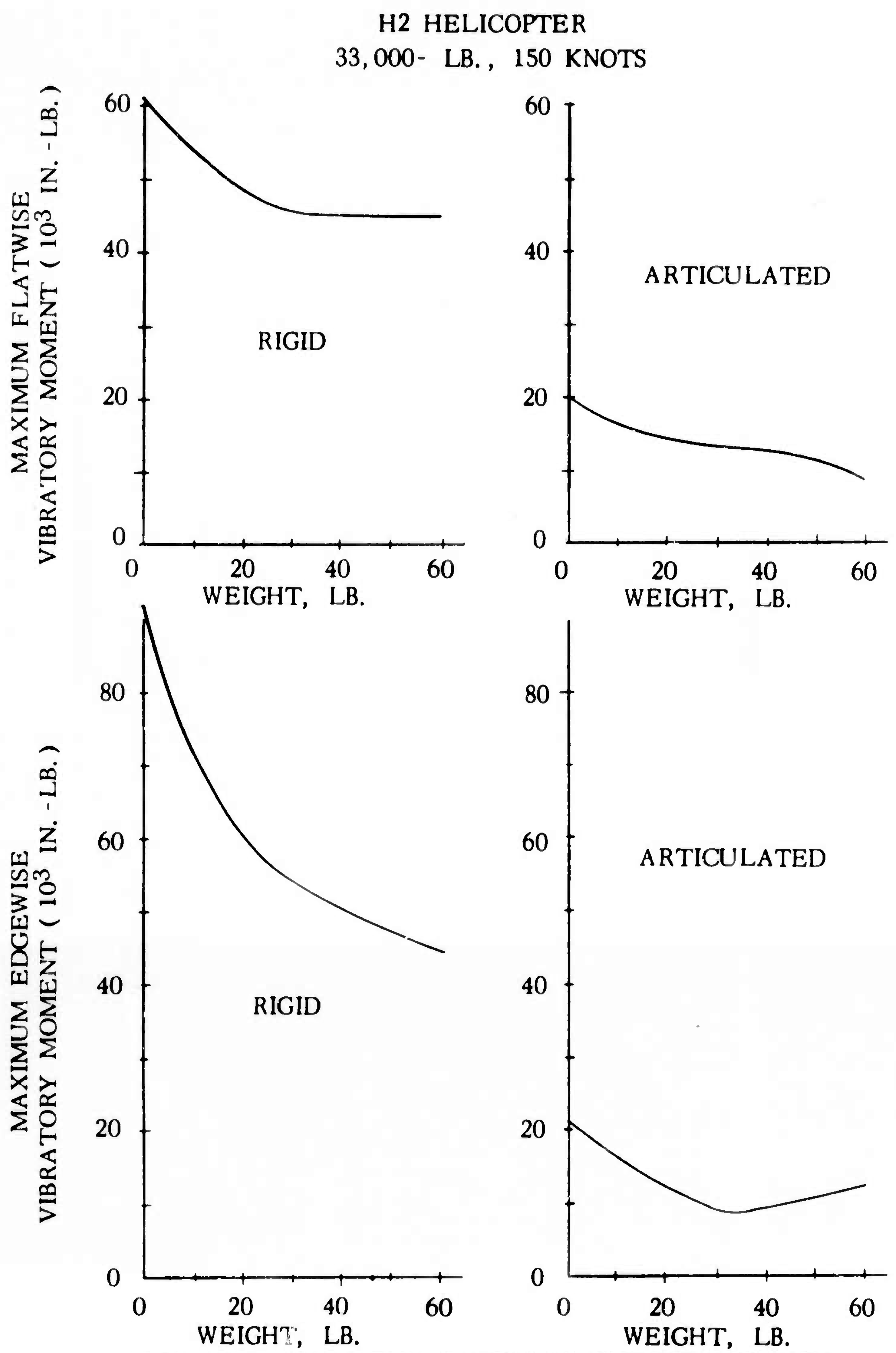


FIG. 10.4 CHANGE IN MAXIMUM BENDING MOMENTS WITH WEIGHT ADDED AT THE BLADE TIP

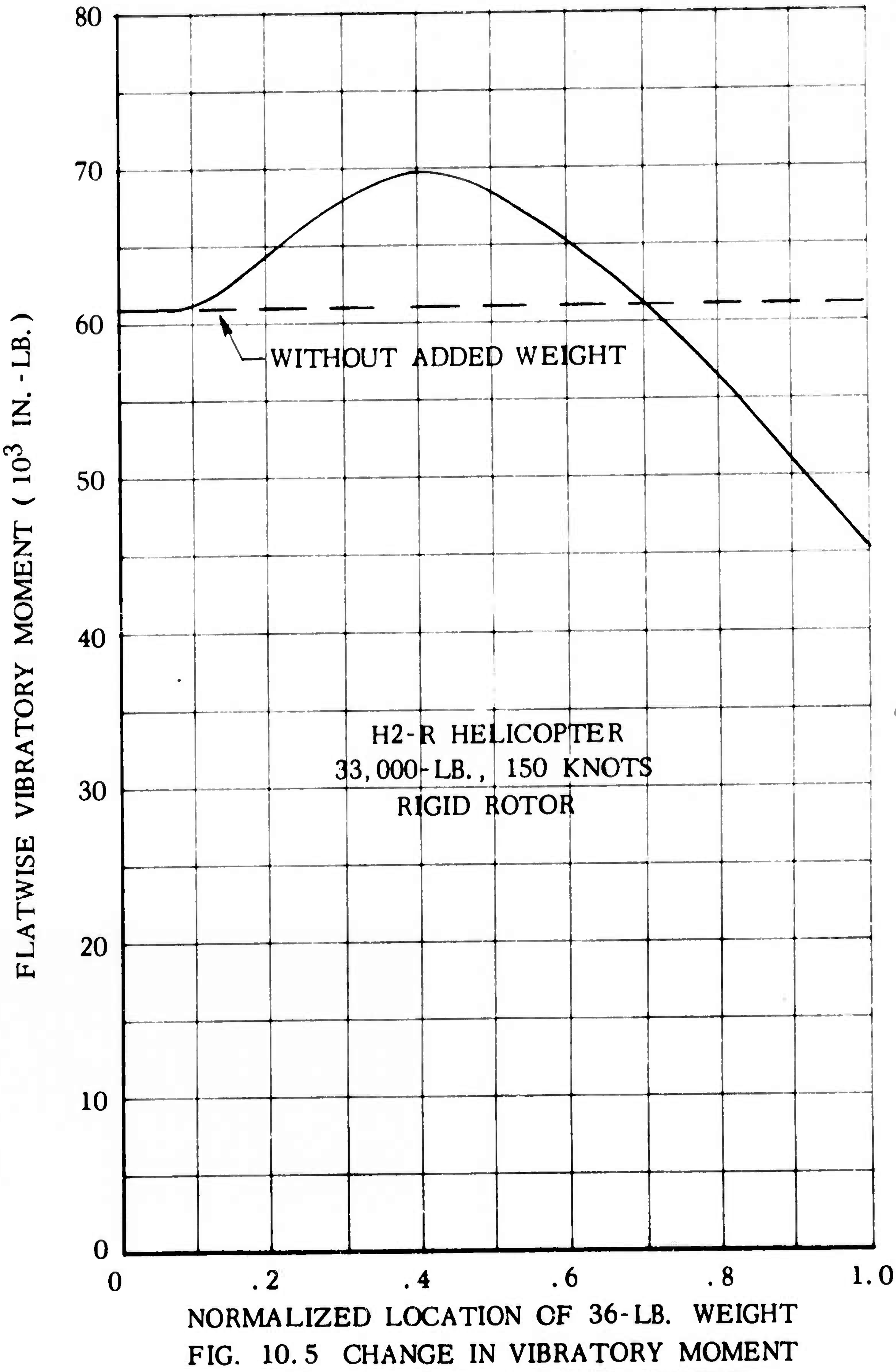


FIG. 10.5 CHANGE IN VIBRATORY MOMENT WITH LOCATION OF ADDED WEIGHT

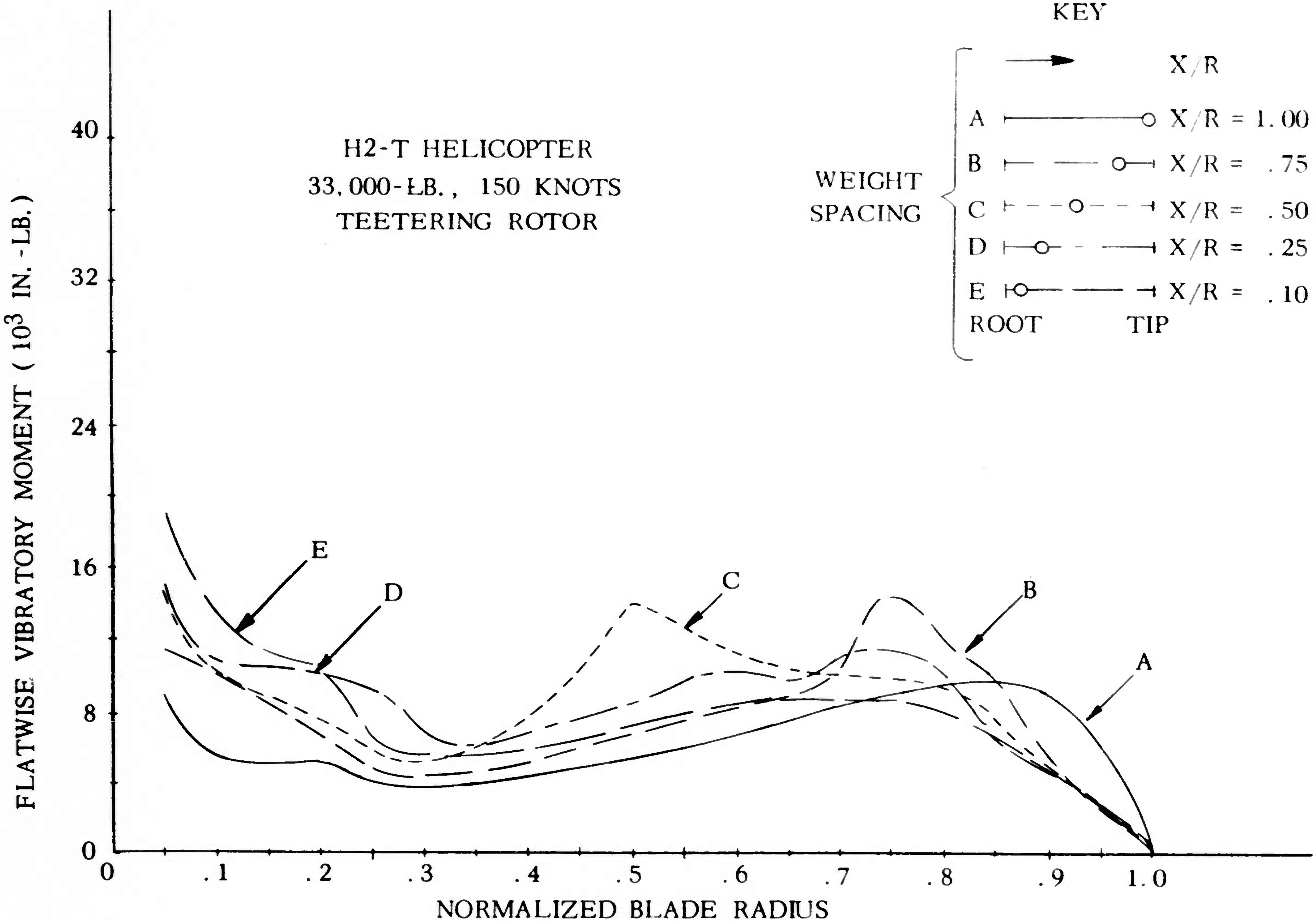


FIG. 10.6 EFFECT OF SINGLE 36-LB. WEIGHT ON FLATWISE MOMENT

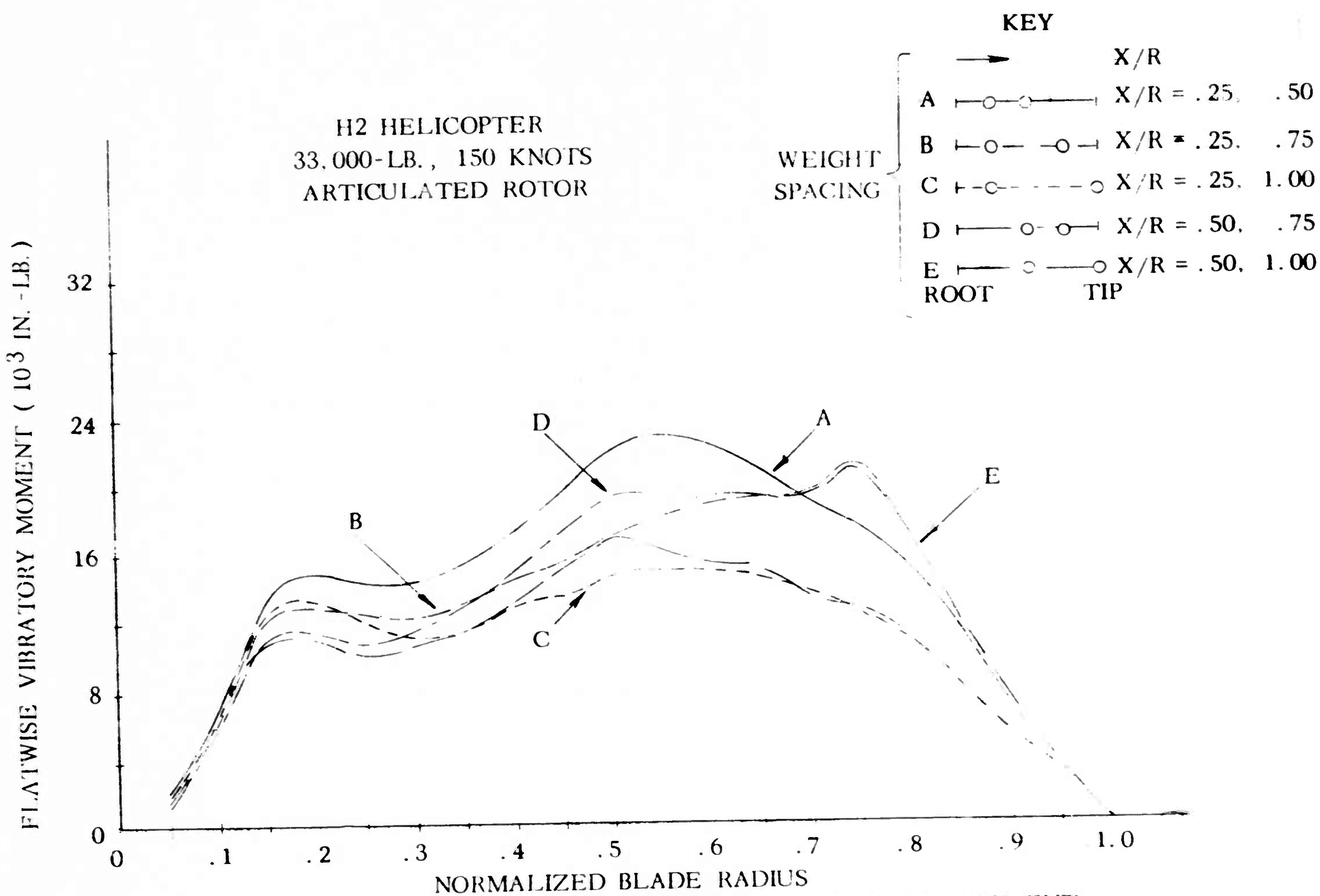


FIG. 10.8 EFFECT OF TWO 18-LB. WEIGHTS ON FLATWISE MOMENT

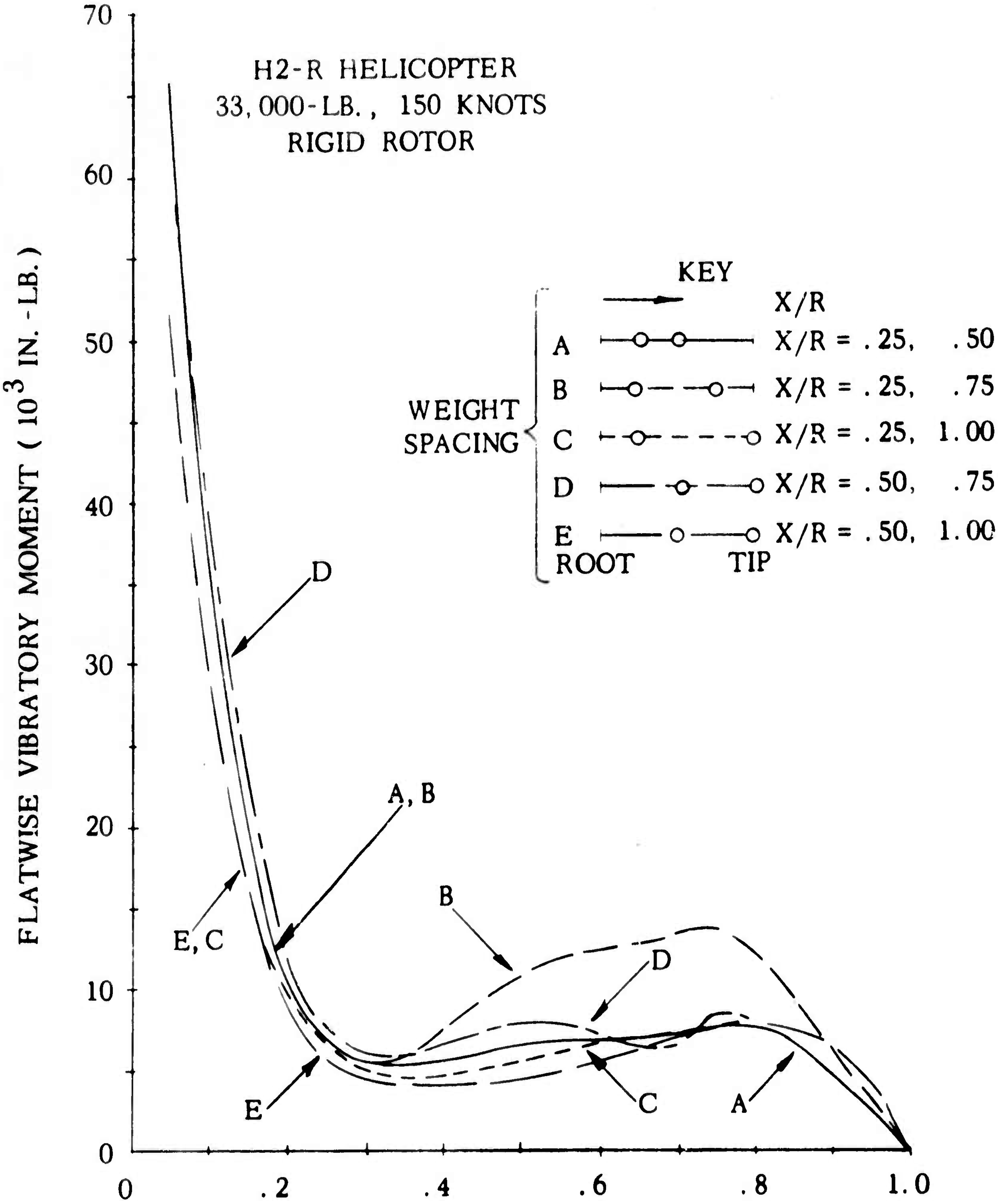


FIG. 10.9 EFFECT OF TWO 18-LB. WEIGHTS ON FLATWISE MOMENT

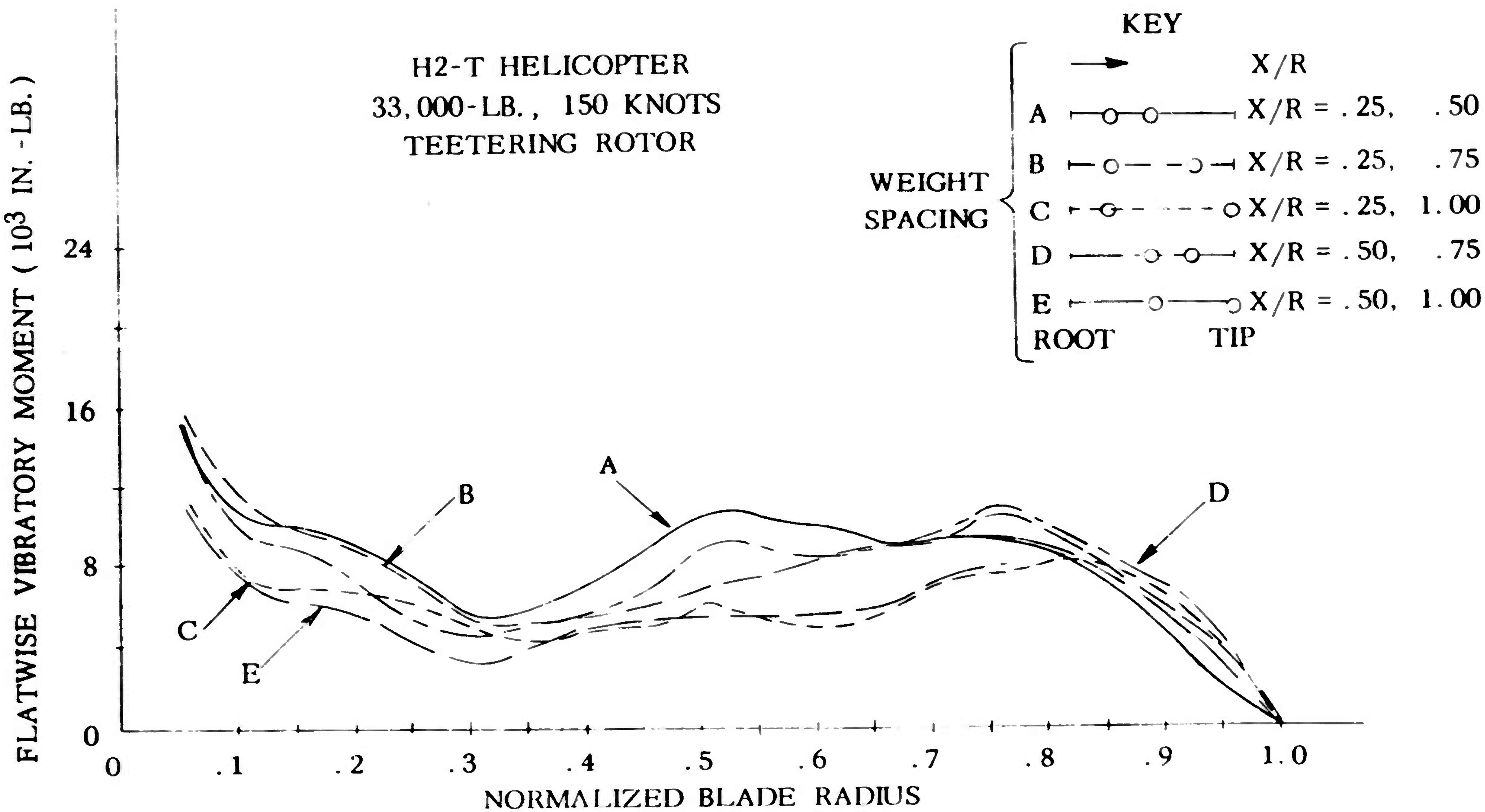


FIG. 10.10 EFFECT OF TWO 18-LB. WEIGHTS ON FLATWISE MOMENT

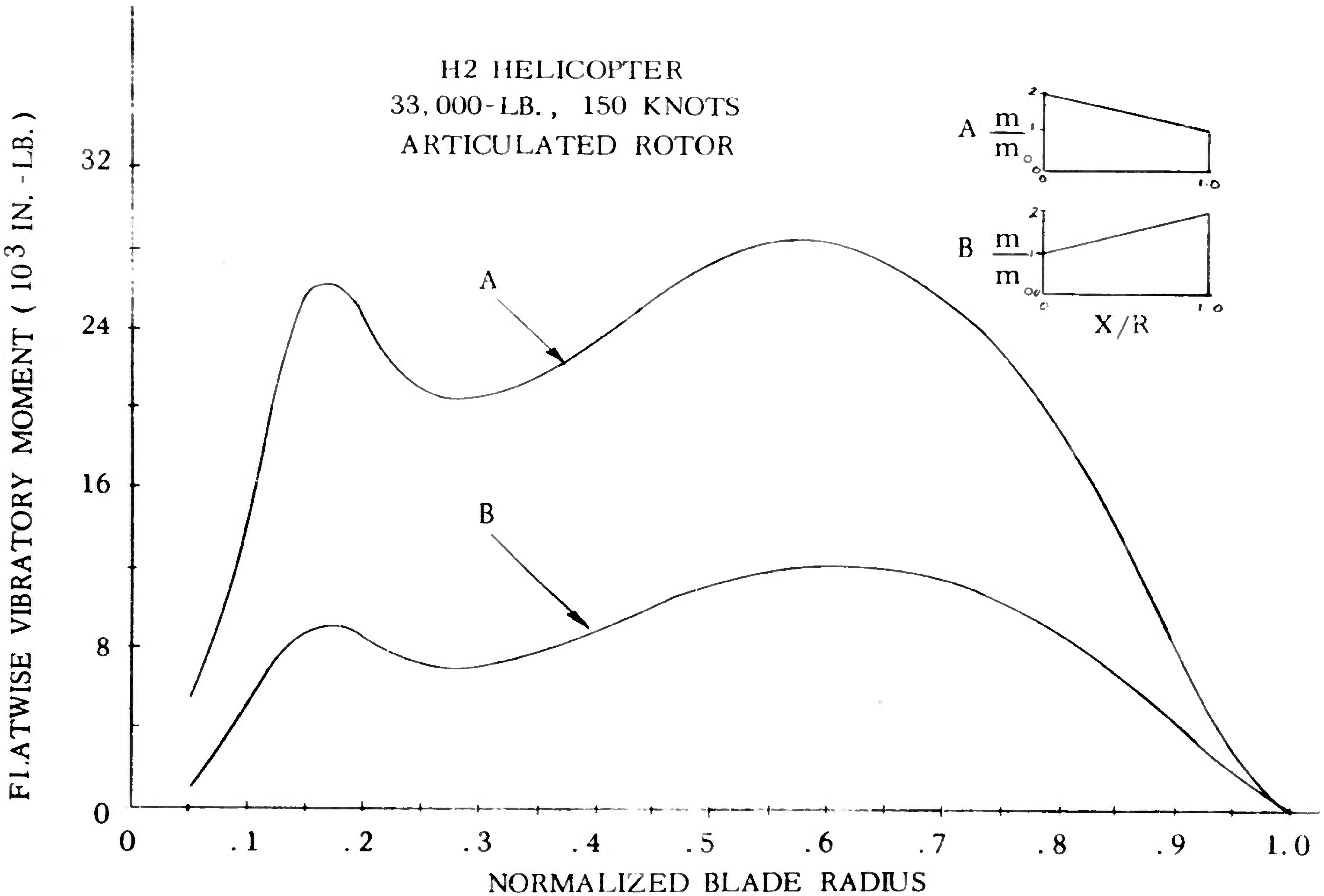


FIG. 10.11 EFFECT OF MASS TAPER ON FLATWISE MOMENT

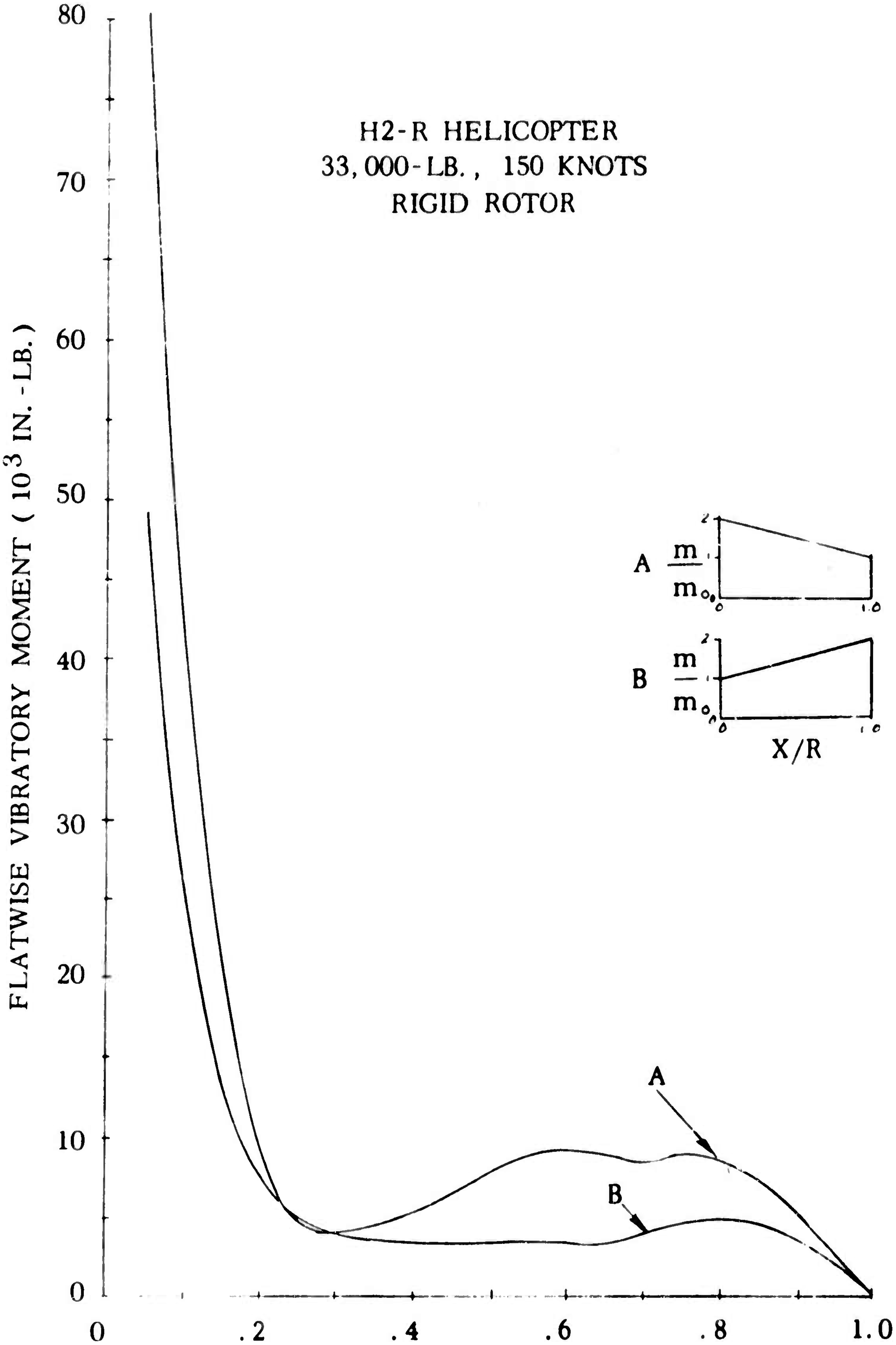


FIG. 10.12 EFFECT OF MASS TAPER ON FLATWISE MOMENT

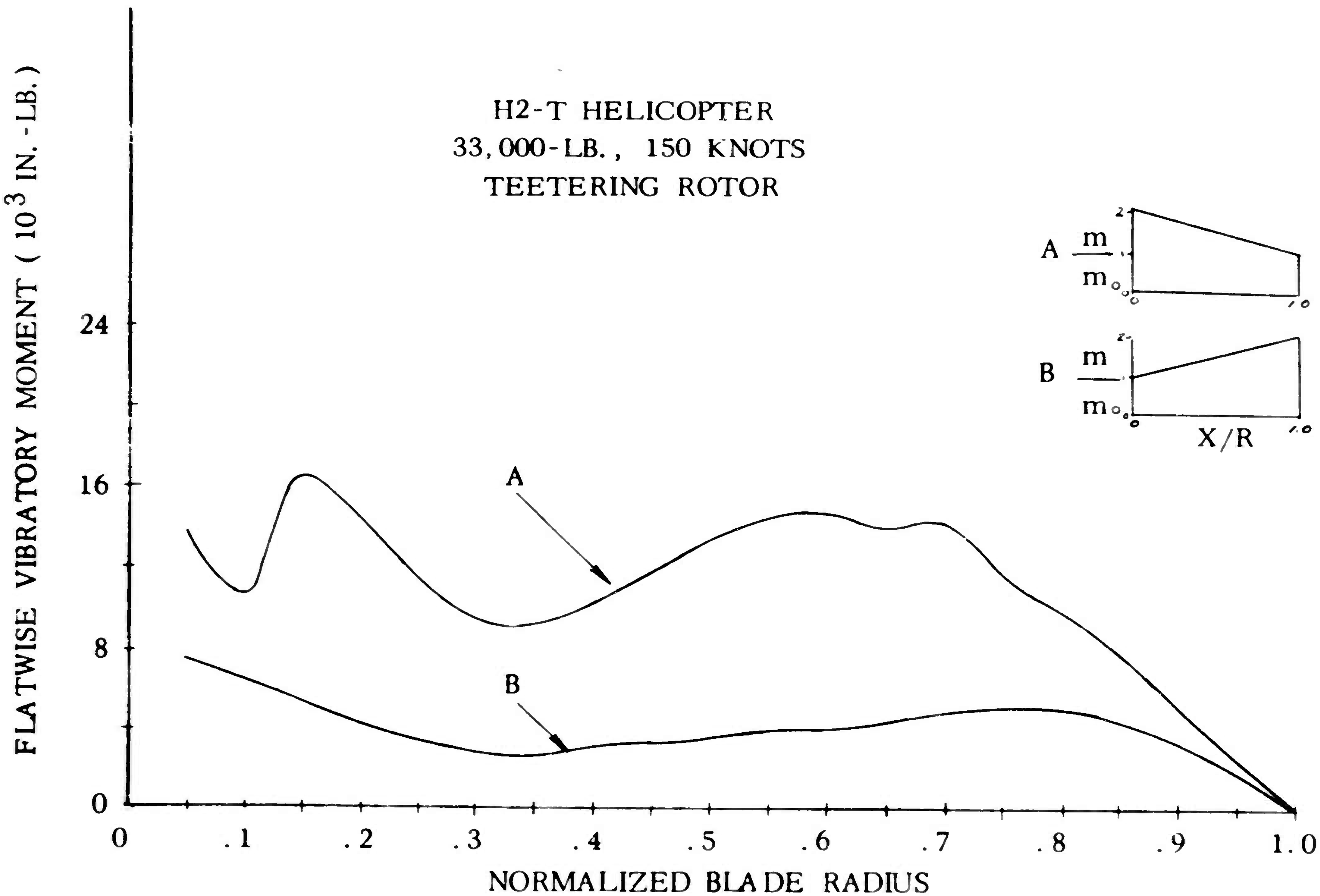


FIG. 10.13 EFFECT OF MASS TAPER ON FLATWISE MOMENT

11. BLADE RESTRAINT VARIATIONS

A. ROTOR HEAD IMPEDANCE

An important feature of the Sikorsky blade dynamic analysis program is that it provides for blade-fuselage coupling. This effect is generally ignored in most blade dynamic studies. Experience at Sikorsky Aircraft indicates that blade-fuselage coupling does not significantly alter one-per-rev blade vibratory stresses, which usually govern blade design, but coupling effects may be important when considering vibrations of the fuselage and higher mode response of the blades.

In the blade-fuselage coupling relationships, the dynamics of the flexible blade are "married" to dynamics of the fuselage by matching blade impedance to fuselage impedance at the rotor head. The "heart" of this analysis consists of two coordinate transformations, one relating forces in the rotating system to forces in the fixed system and the other relating angular and linear displacements in the rotating system to the fixed system. For an n-bladed helicopter, results of the calculation give the n/rev. vertical and coupled-lateral-torsion fuselage response at a particular airspeed. Also obtained is the n-1, n, and n+1/rev. flatwise-edgewise blade response for that airspeed.

Blade-fuselage coupling is shown in Figure 11. 1. A flow chart relating blade fuselage coupling to aerodynamic and blade dynamic analysis is given in Figure 11. 2. In applying blade-fuselage coupling relationships to a blade dynamic analysis, a fuselage analysis is not necessarily required. The basic equations can be used for studies of the effect of blade root impedance on blade dynamics.

The following matrix of hub motion was chosen as a reasonable set for a standard. The zeros are due to decoupling of the vertical from the lateral torsion response. Also, since the numbers are real, no fuselage damping has been included.

$$
\begin{bmatrix} X \\ Y \\ Z \\ \phi_F \\ \theta_F \\ \psi_F \end{bmatrix}
=
\begin{bmatrix}
1093.85 & 0 & -217.25 & 0 & 67.48 & 0 \\
0 & -532.07 & 0 & 20.02 & 0 & -.87 \\
-217.25 & 0 & -103.29 & 0 & -6.60 & 0 \\
0 & 20.02 & 0 & 3.79 & 0 & -.01 \\
67.48 & 0 & -6.60 & 0 & 5.17 & 0 \\
0 & -.87 & 0 & -.01 & 0 & -.01
\end{bmatrix}
\begin{bmatrix} S_x \\ S_y \\ S_z \\ M_{xx} \\ M_{yy} \\ M_{zz} \end{bmatrix}
$$

* All values to be multiplied by 10^{-8}

Seven cases of hub impedance were considered in the investigation. These were the standard case, described previously, a rigid hub case,and cases in which the basic hub admittance matrix was multiplied by factors of 10^{-2}, 10^{-1}, 10^{1}, 10^{2},and 10^{3}. Shown in Figures (11.3 through (11.8 are plots of sine and cosine components of shear versus impedance for the 5, 6 and 7/rev. frequencies. As admittance is increased or impedance is decreased, shears are noted to approach zero. This is expected,for the blade approaches the free-free condition.

Flatwise and edgewise vibratory components of root motion for the minimum hub impedance ranged from 7×10^{-5} inches to 8×10^{-3} inches, and reflected a substantial change in blade mode shape from the rigid hub condition. For this change in mode shape,there would be a corresponding change in blade natural frequency. Results indicate that blade fuselage coupling may have to be taken into account in predicting higher harmonic blade and associated fuselage response.

B. BOUNDARY CONDITIONS

Table 2. 5 summarizes the three variations in blade boundary conditions which were investigated. Here, the blade was taken as (1) articulated flatwise, cantilevered edgewise; (2) cantilevered flatwise, articulated edgewise; and (3) articulated flatwise, articulated edgewise. Variations considered under this part of the study represent limit conditions for the root flexibility study of Section 11-C.

Figure 11. 9 gives the radial distribution of vibratory flatwise bending moment for the three cases considered. As would be expected, the flatwise root moment increases with degree of flatwise restraint. There is zero flatwise moment for the double articulated blade; more root moment with the blade articulated flatwise, cantilevered edgewise; and greatest flatwise root moment for the cantilevered flatwise, articulated edgewise case. Shown in Figure 11. 9a are corresponding radial distributions of edgewise vibratory moment. Here, trends of root vibratory are in proportion to degree of edgewise root restraint.

C. BLADE ROOT FLEXIBILITY

The schedule followed for varying root flexibility is given by Table 2. 6. Variations were carried out on the H2 helicopter at 150 knots. Results are presented in Figures 11. 10 through 11. 15.

Change in flatwise vibratory moment with change in flatwise root restraint is given in Figure 11. 10. Here, flatwise root restraint was varied from fully articulated to fully cantilevered. Edgewise restraint was kept articulated as flatwise root flexibility varied. Note the change in vibratory moment distribution as stiffness at the root increases. Distributions shown for root flexibilities ranging from 0 to 100, 000 in. -lbs. /rad. are typical of articulated blades, with the maximum occurring at about two-thirds blade radius. Root flexibility of one million in. -lbs. /rad. is seen to result in a root moment about equal to the outboard moment. As root flexibility is further increased, we observe an associated increase in root moment and some decrease in moment at the outboard blade stations.

Effects of change in edgewise root flexibility, while holding flatwise articulated, are shown in Figures 11. 12 and 11. 13. Given in Figure 11. 13 are changes in corresponding edgewise moment envelopes, while Figure 11. 12 gives corresponding changes in flatwise moments. The high value of edgewise moment as edgewise restraint becomes infinite is attributed to resonance. That is, the first edgewise mode for the blade considered approaches one-per-rev with cantilever restraint. This is avoided in design of rigid rotor systems by following the in-plane tuning criteria as set forth in Section 4. Corresponding changes in flatwise moments with change in edgewise restraint (Figure 11. 12) do not appear to be significant until the restraint approaches 10 million in. -lbs. /rad. Variations shown are due to flatwise-edgewise coupling.

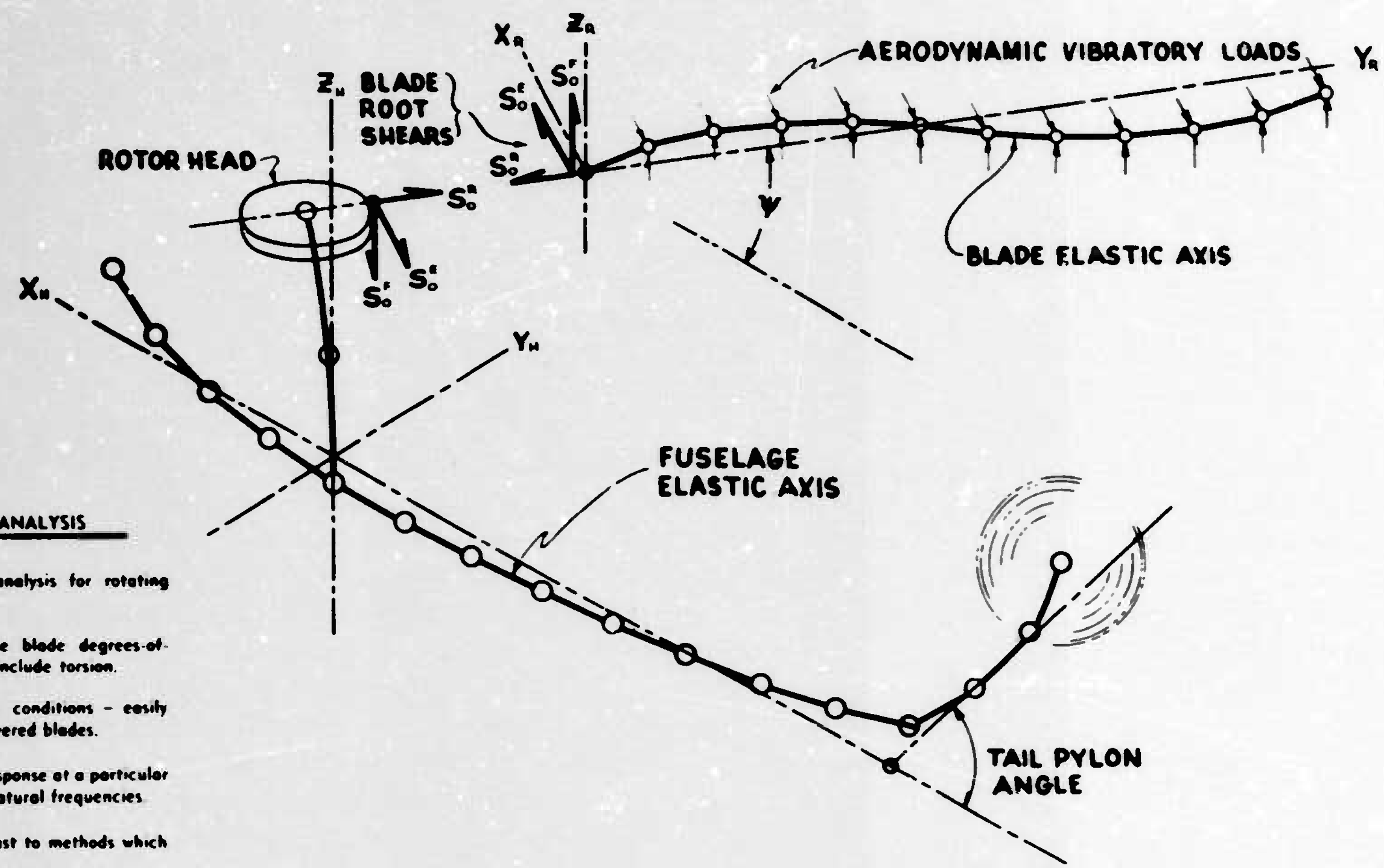
Presented in Figures 11. 14 and 11. 15 are effects on the radial distribution of flatwise and edgewise vibratory moments due to increasing the amount of damping at the lag hinge. For high amounts of damping, trends observed are seen to be similar to results obtained by varying edgewise root restraint.

In addition to parametric studies just described, an investigation of root flexibility was carried out on the Lockheed CL-475, prototype rigid rotor helicopter. Proper treatment of blade root flexibility is of prime importance in design of rigid rotor systems. Rigid rotor designers point out that the term "rigid" is a misnomer and that "hingeless" is a preferred definition. In truth, the root region of these blades is far from being a mathematical cantilever. Designed flexibility contributes to a root restraint, which is between a theoretical rigid and hinged condition.

For the Lockheed CL-475 helicopter, effects of root flexibility on calculated vibratory bending moments and stresses are given in Figures 11. 16, 11. 17, 11. 18, and 11. 19. Calculations were made at 100 mph. For the first three figures, flatwise root flexibility has been varied, while edgewise restraint is held to a value representative of the actual CL-475 design.

The first plot, Figure 11. 16, gives the distribution of flatwise vibratory moments along the blade for an articulated version of the CL-475. Observe that the curve is again typical of articulated blades in that the maximum vibratory moment occurs at about two-thirds blade radius. Maximum value is ±2100 inch-pounds. The second plot, Figure 11. 17, shows corresponding flatwise vibratory moments for a theoretically rigid root restraint. In this case, the outboard blade moment is seen to increase to ±2700 inch-pounds; while at the root, moments reach a value in excess of ±8000 inch-pounds. Finally, shown in Figure 11. 18 are calculated moments for a blade with selected flatwise root restraint. For thid condition, outboard blade moments are reduced to ±650 inch-pounds, while root vibratory moments increase to about double the maximum level for the articulated blade. Toward the root, more blade area is required to carry centrifugal loads, so a section modulus can be selected for a semirigid blade that will yield vibratory stress levels comparable to those of an articulated design.

Sensitivity of edgewise stresses to proper tuning is illustrated by Figure 11. 19. Lockheed recommends a frequency ratio of $1.4\,\Omega$, which is apparent from the plot, where vibratory stresses are seen to become excessively large as the first edgewise mode of the blade approaches one-per-rev. Results given are for a neutral c. g. fuselage trim condition. Center-of-gravity shifts can increase edgewise stresses due to increased first harmonic bending and associated Coriolis forces.



ROTOR BLADE DYNAMIC ANALYSIS

- Based on extension of Myklestad's analysis for rotating beams.
- Provides 24 flatwise and 24 edgewise blade degrees-of-freedom with coupling due to twist. Can include torsion.
- Has provision for variable boundary conditions – easily amended for handling teetering or cantilevered blades.
- Can be used for calculating vibratory response at a particular frequency, total blade response, or blade natural frequencies.
- Simulates blade elastic curve, in contrast to methods which divide blade into rigid segments.
- Has provision for a lag damper.
- Aerodynamic damping included in the equations.
- Allows for motion of rotor head.
- Can be used for finding the response of blade to arbitrary excitations, such as stepped inputs.
- Forced response analysis will yield flatwise and edgewise deflections, slopes, moments, shears, and stresses at each of the 24 blade stations for 10 degree azimuth intervals.
- Equations are in complex form. This yields phasing when calculating vibratory forced response of the blade at a particular frequency.

BLADE-FUSELAGE COUPLING

- Dynamics of the flexible blade are "married" to dynamics of the fuselage by matching blade root impedance to fuselage impedance at the rotor head.
- The "heart" of this analysis consists of two coordinate transformations, one relating forces in the rotating system to forces in the fixed system, the other relating angular and linear displacements in the rotating system to the fixed system.
- Results of the calculation give the n/rev vertical and coupled lateral torsion fuselage response at a particular airspeed.
- Also, obtained is the n-1, n, and n+1 rev flatwise-edgewise blade response for that airspeed.

FUSELAGE FORCED RESPONSE ANALYSIS

- Based on a direct inverse solution of the dynamic matrix.
- Will handle up to 70 degrees-of-freedom.
- Has provision for calculating the forced response due to any vibratory force or moment at any fuselage station, or any combination of forces or moments.
- Structural damping may be included.

FIGURE 11.1 COUPLED BLADE-FUSELAGE DYNAMIC ANALYSIS

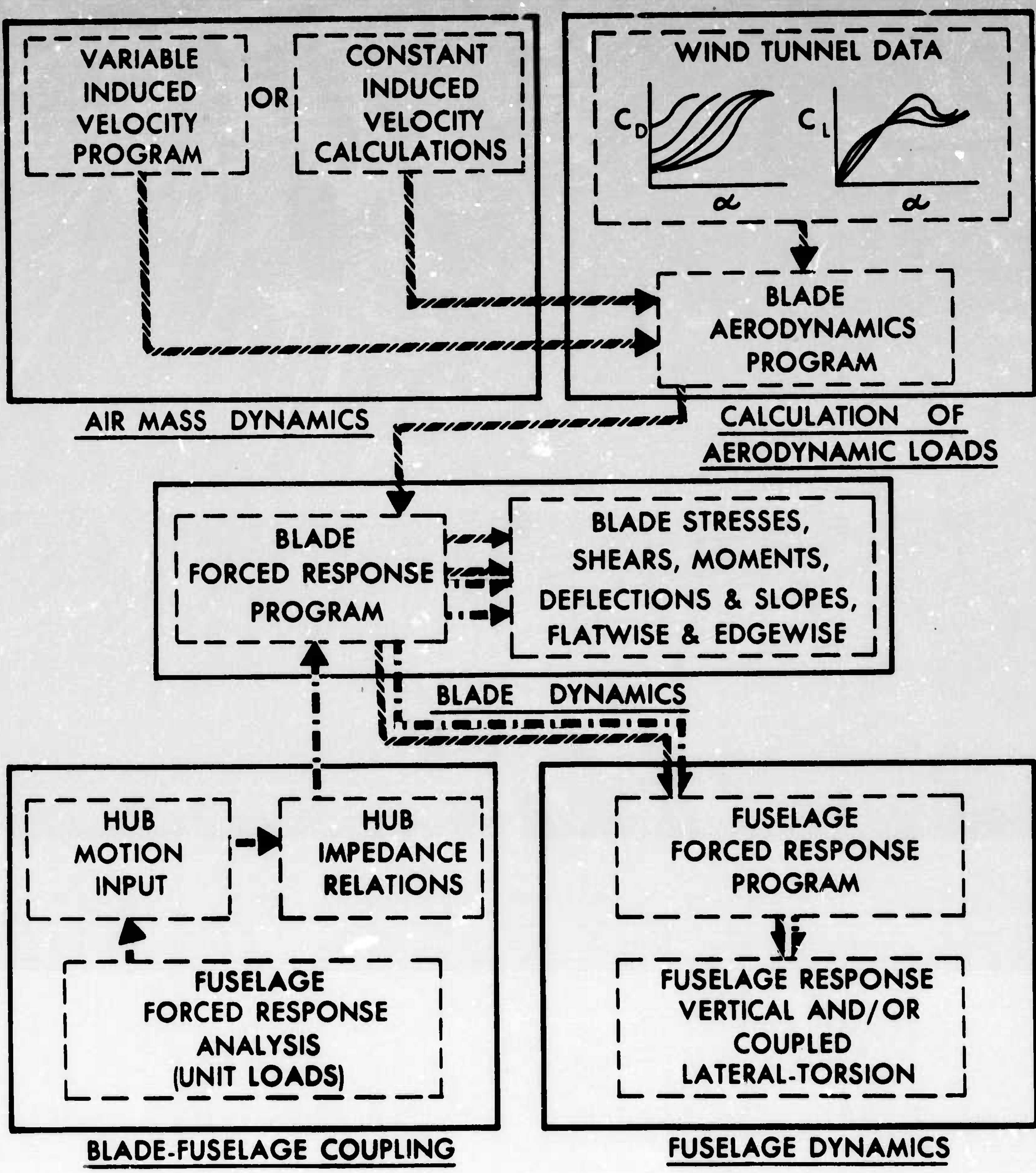


FIGURE 11.2 BLOCK DIAGRAM FOR AEROELASTIC ANALYSIS

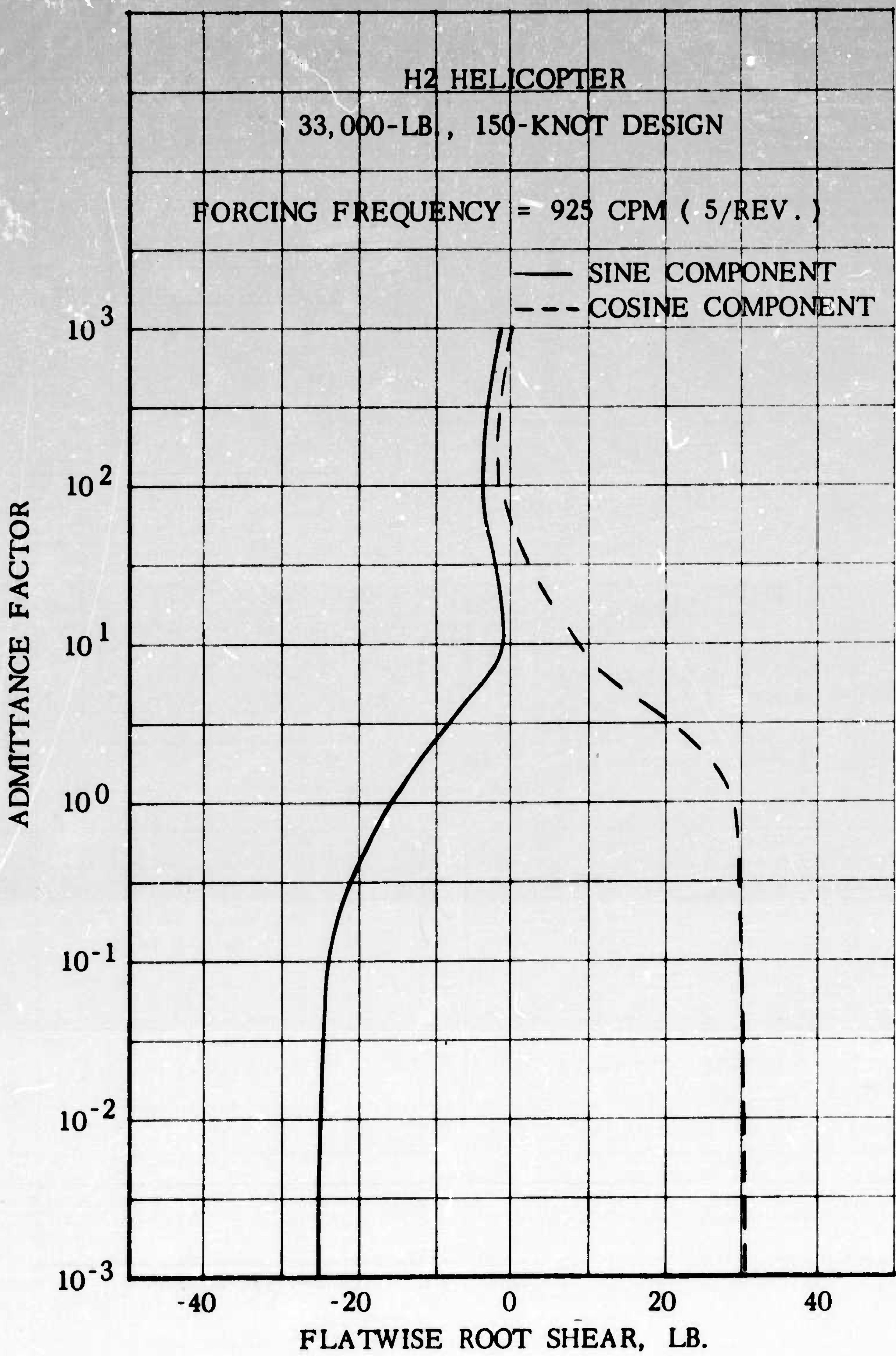


FIG. 11.3 EFFECT OF ROTOR HUB MOTION ON BLADE ROOT FLATWISE SHEAR

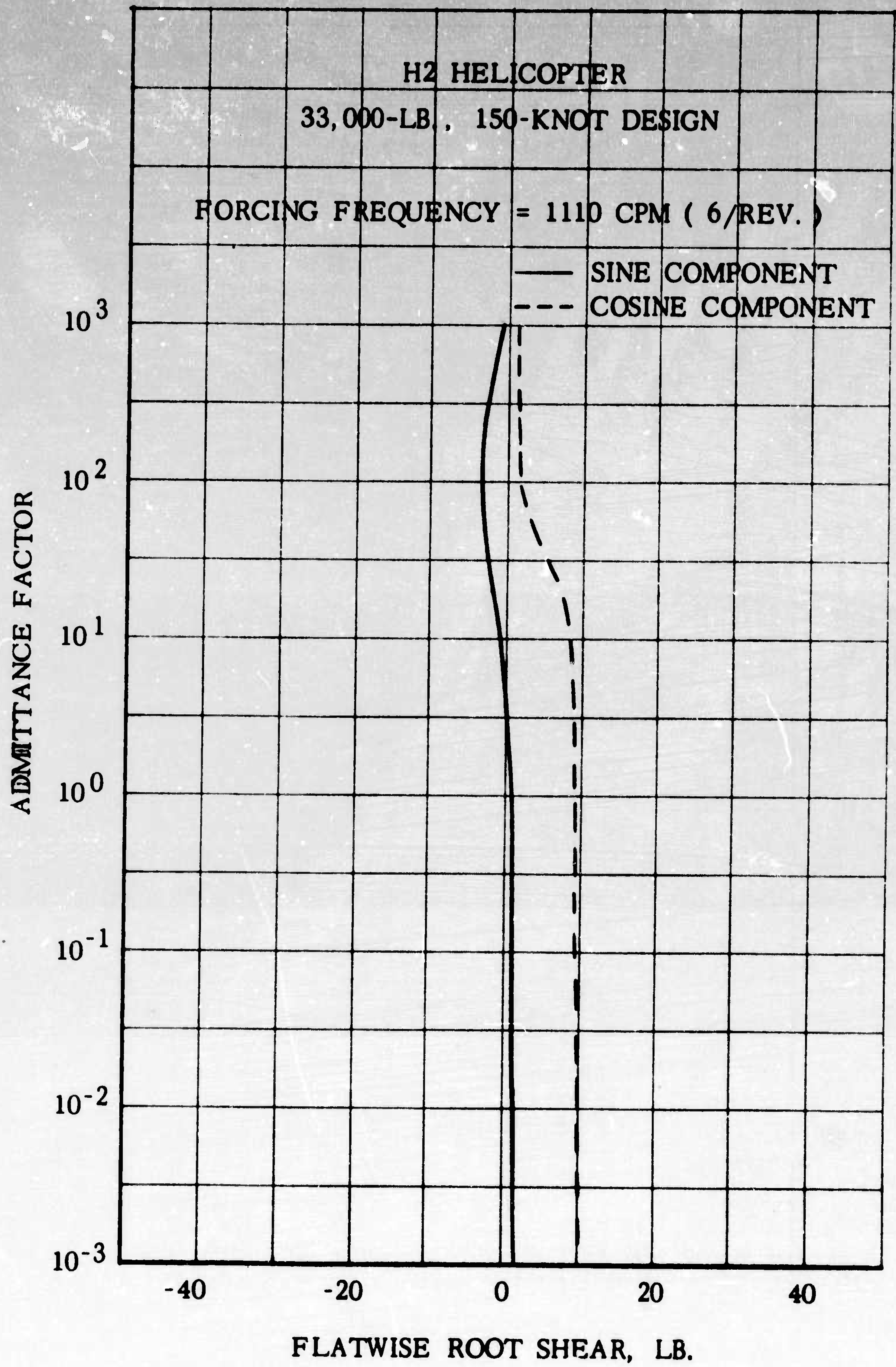


FIG. 11.4 EFFECT OF ROTOR HUB MOTION ON BLADE ROOT FLATWISE SHEAR

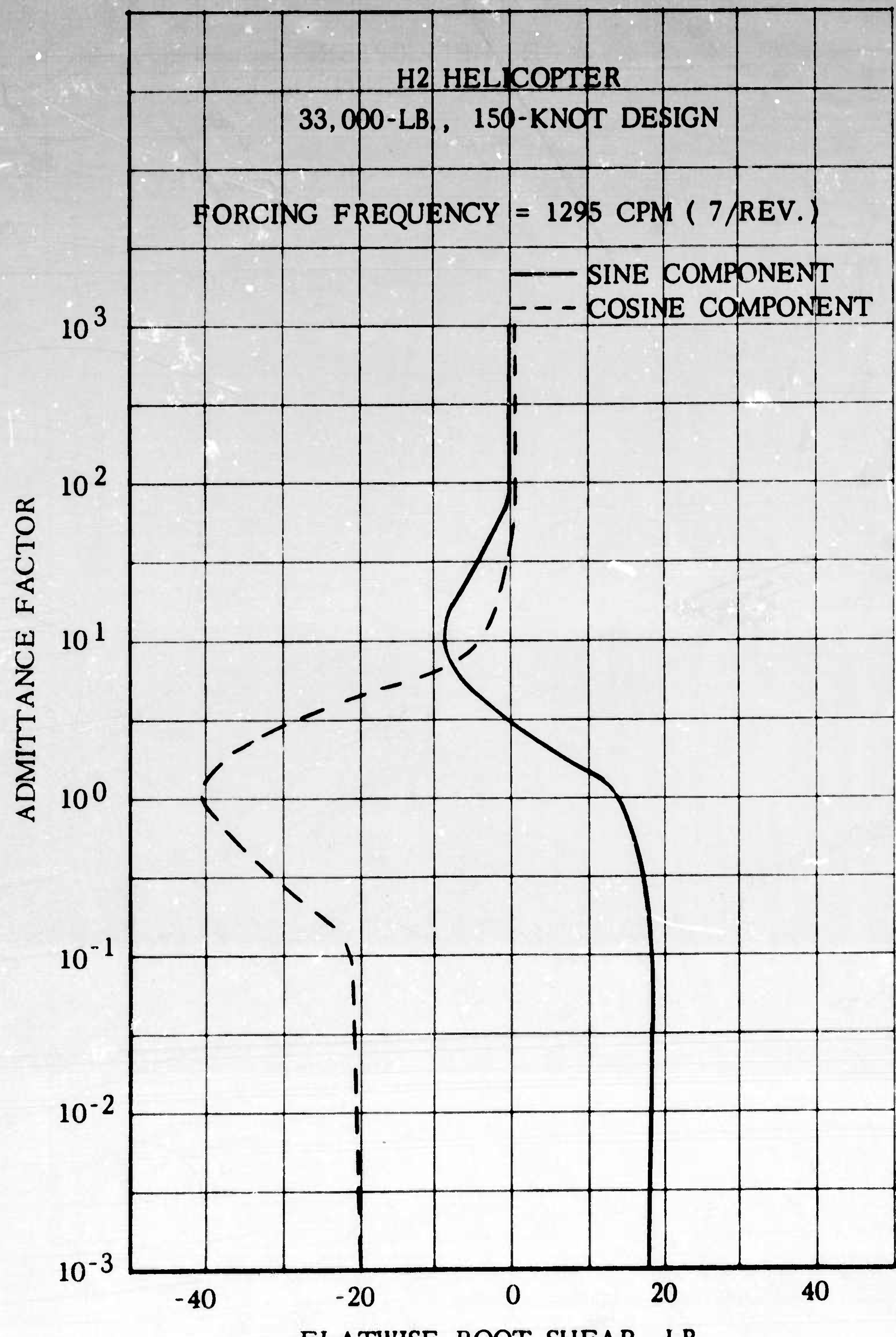


FIG. 11.5 EFFECT OF ROTOR HUB MOTION ON BLADE ROOT FLATWISE SHEAR

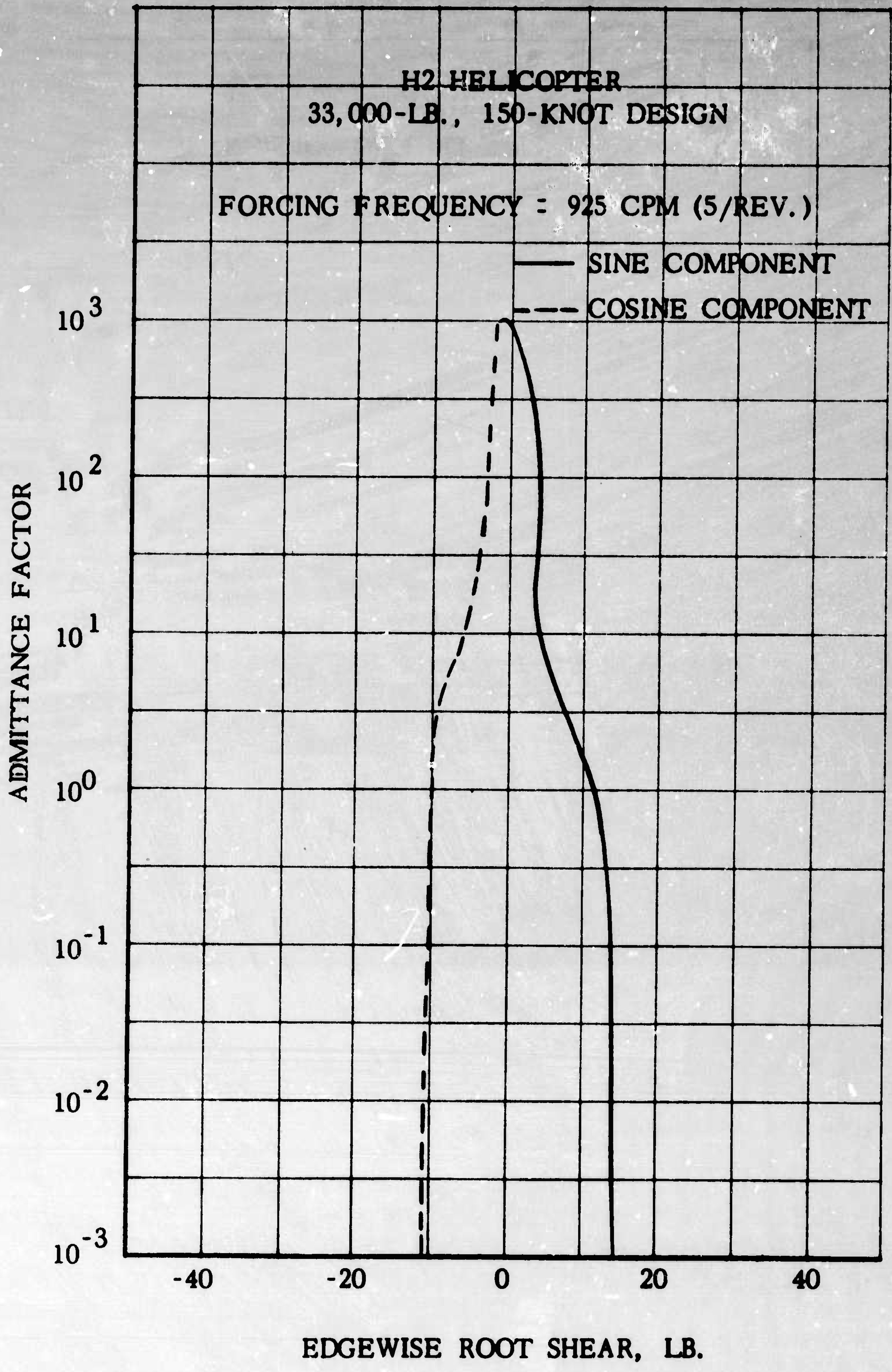


FIG. 11.6 EFFECT OF ROTOR HUB MOTION ON BLADE ROOT EDGEWISE SHEAR

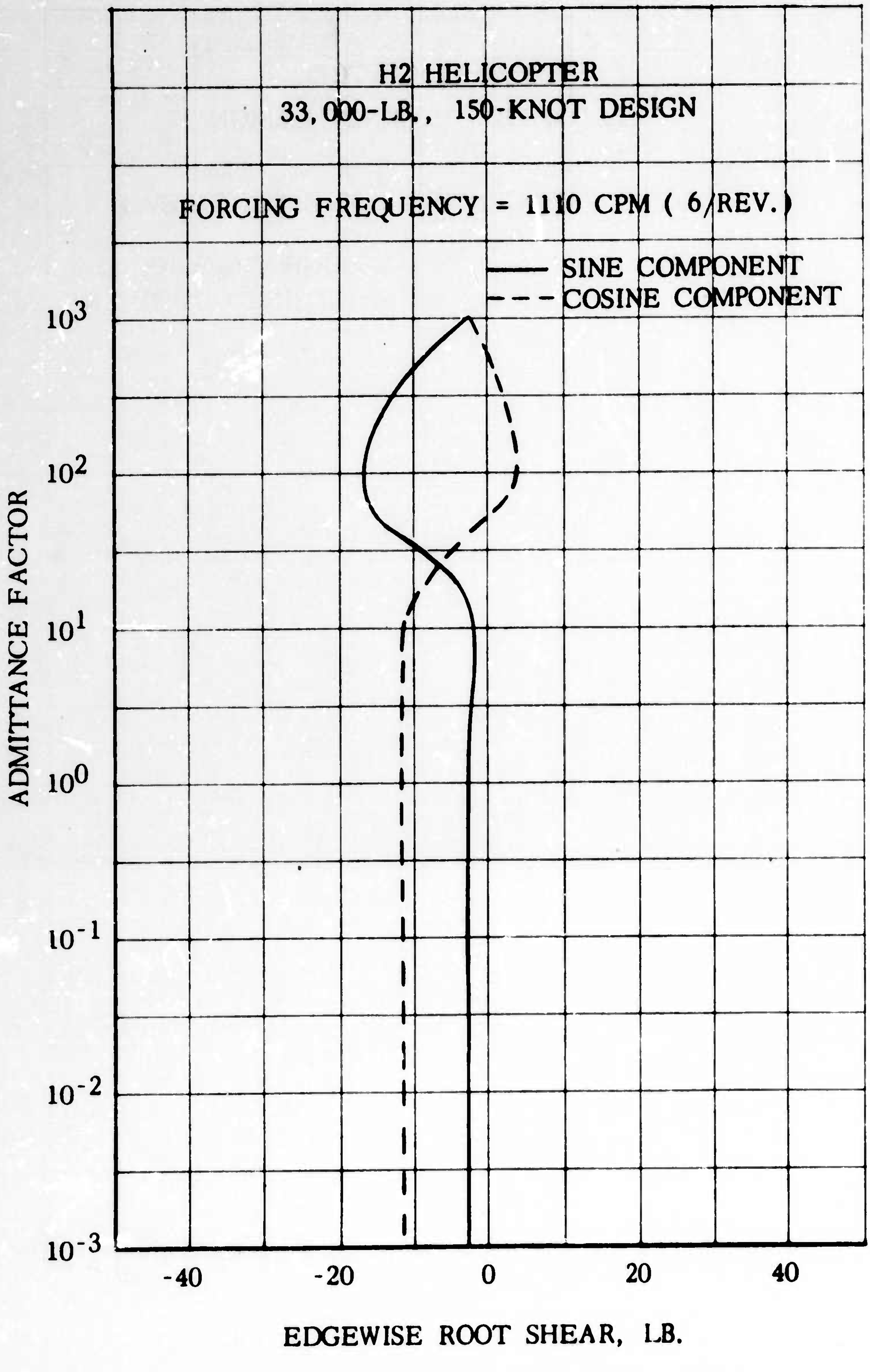


FIG. 11.7 EFFECT OF ROTOR HUB MOTION ON BLADE ROOT EDGEWISE SHEAR

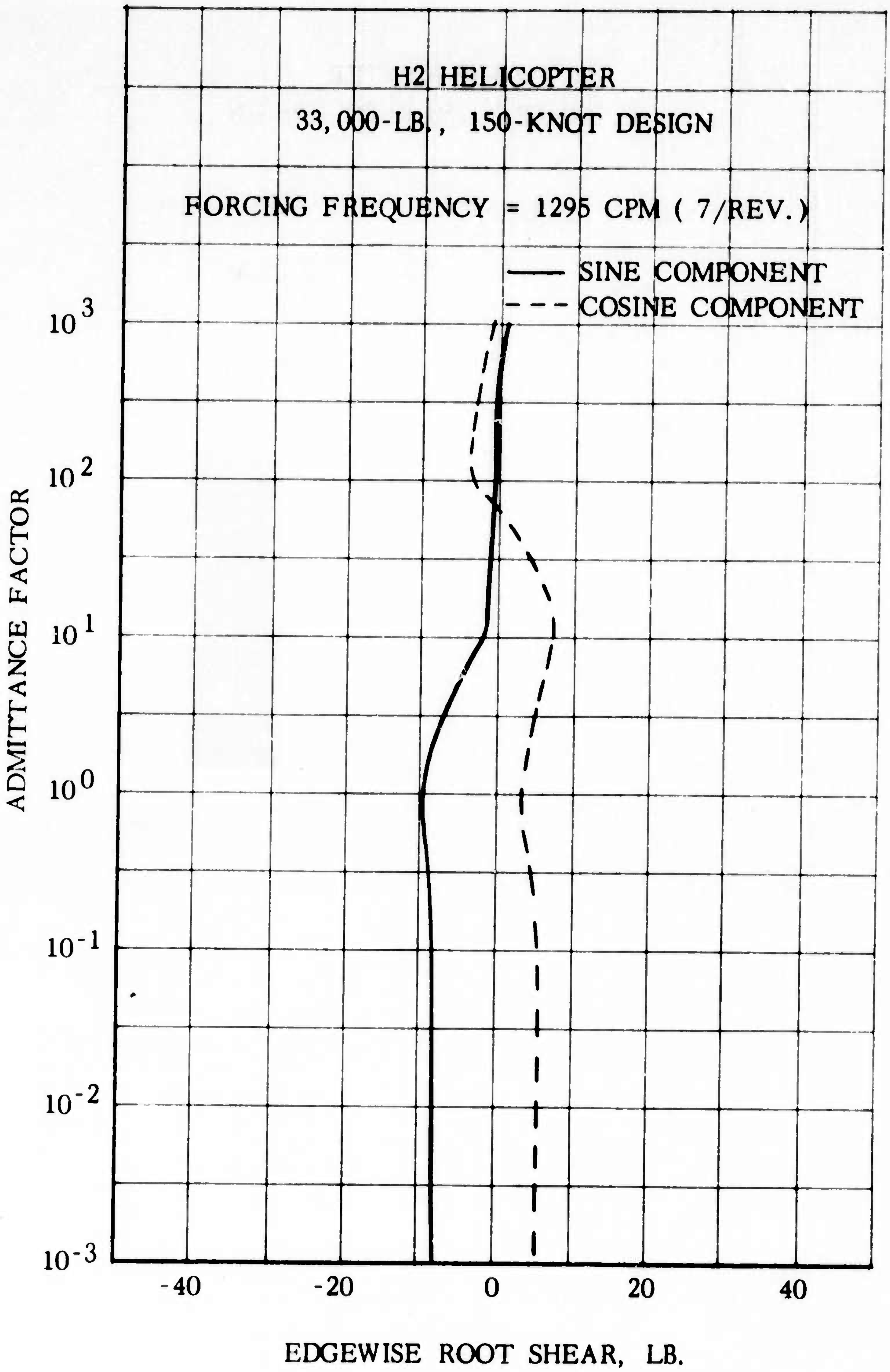


FIG. 11.8 EFFECT OF ROTOR HUB MOTION ON BLADE ROOT EDGEWISE SHEAR

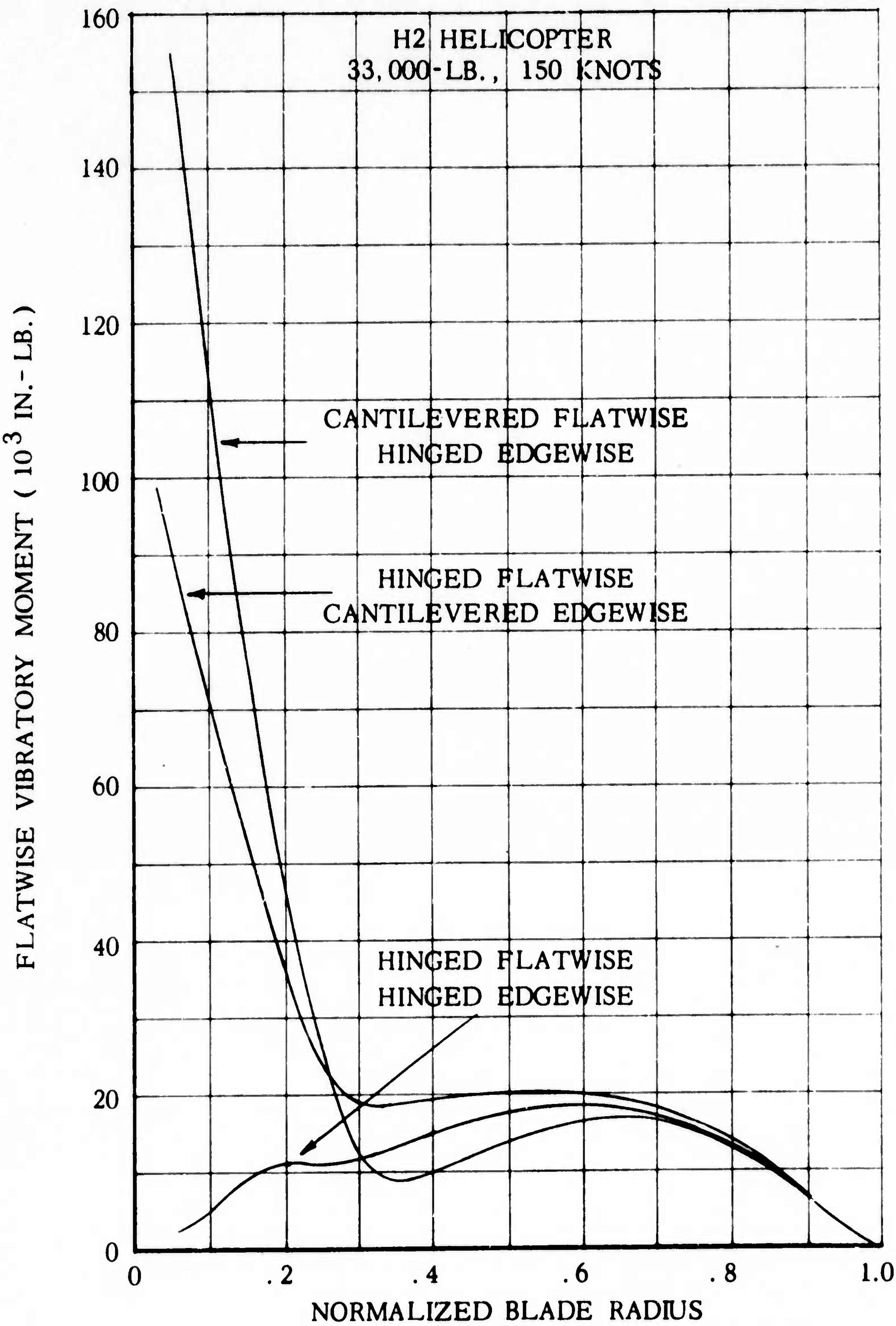


FIG. 11.9 CHANGE IN FLATWISE MOMENT WITH CHANGE IN ROOT RESTRAINT

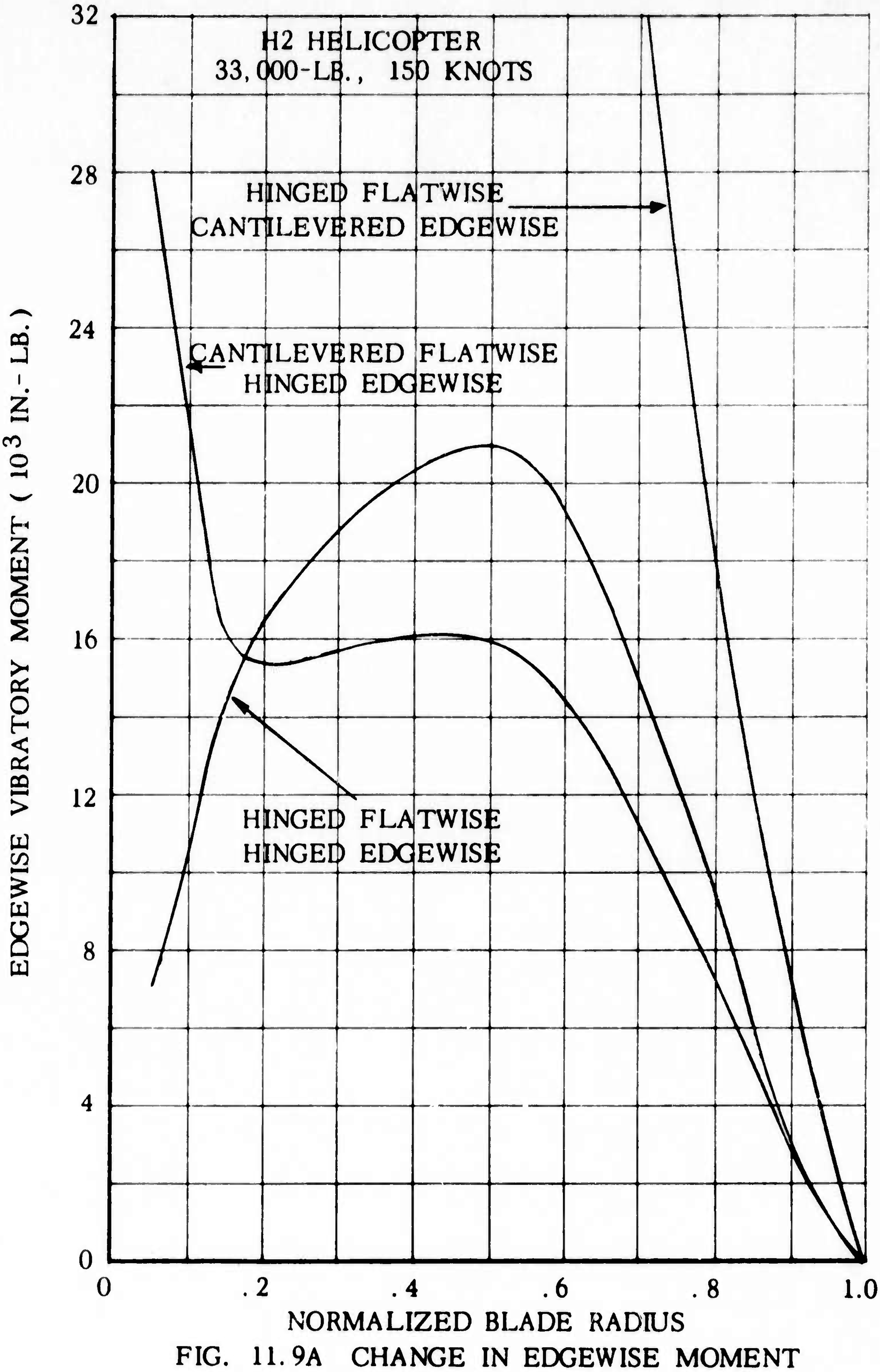


FIG. 11.9A CHANGE IN EDGEWISE MOMENT WITH CHANGE IN ROOT RESTRAINT

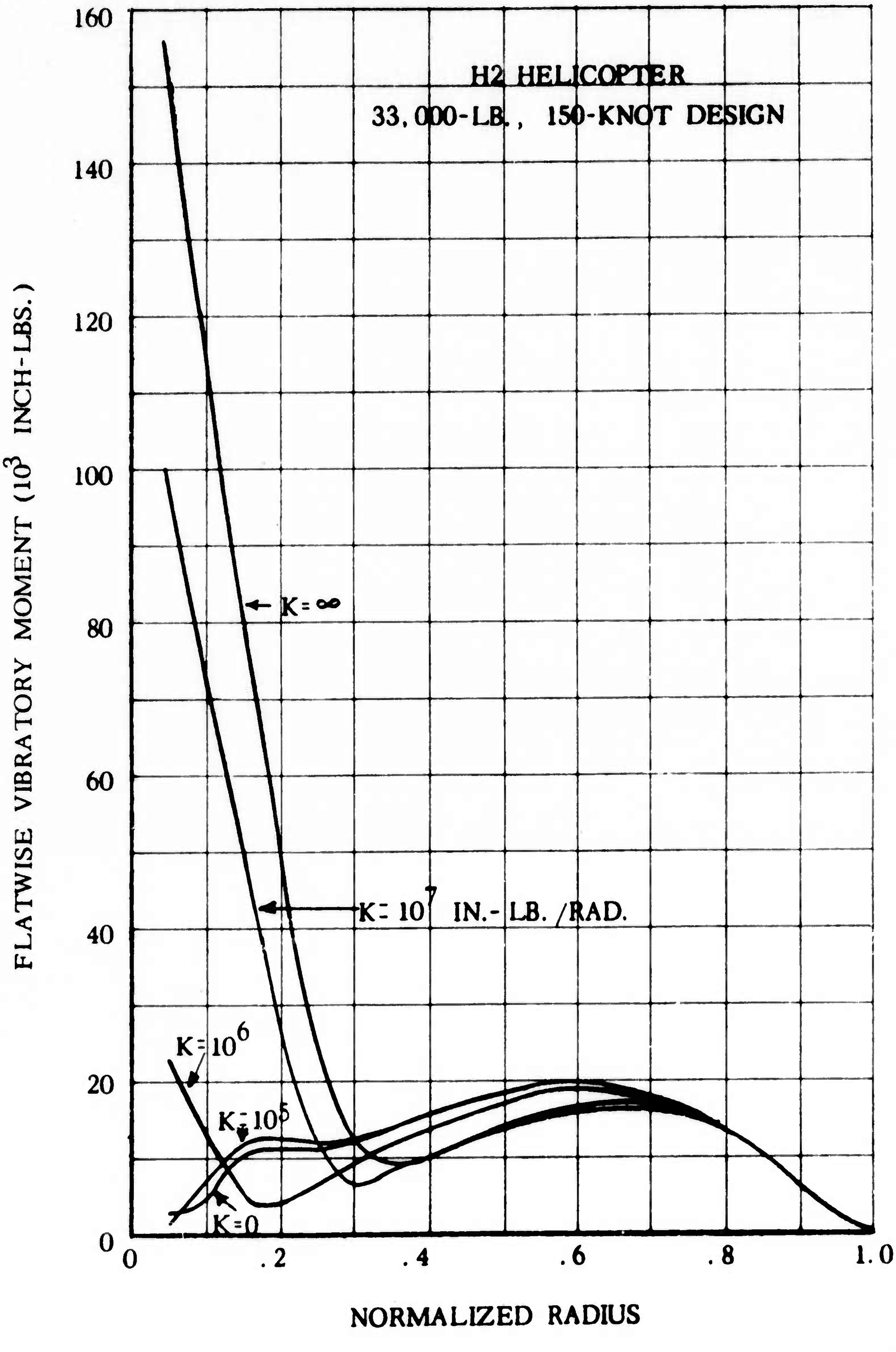


FIG. 11.10 EFFECT OF FLATWISE ROOT FLEXIBILITY ON FLATWISE MOMENT

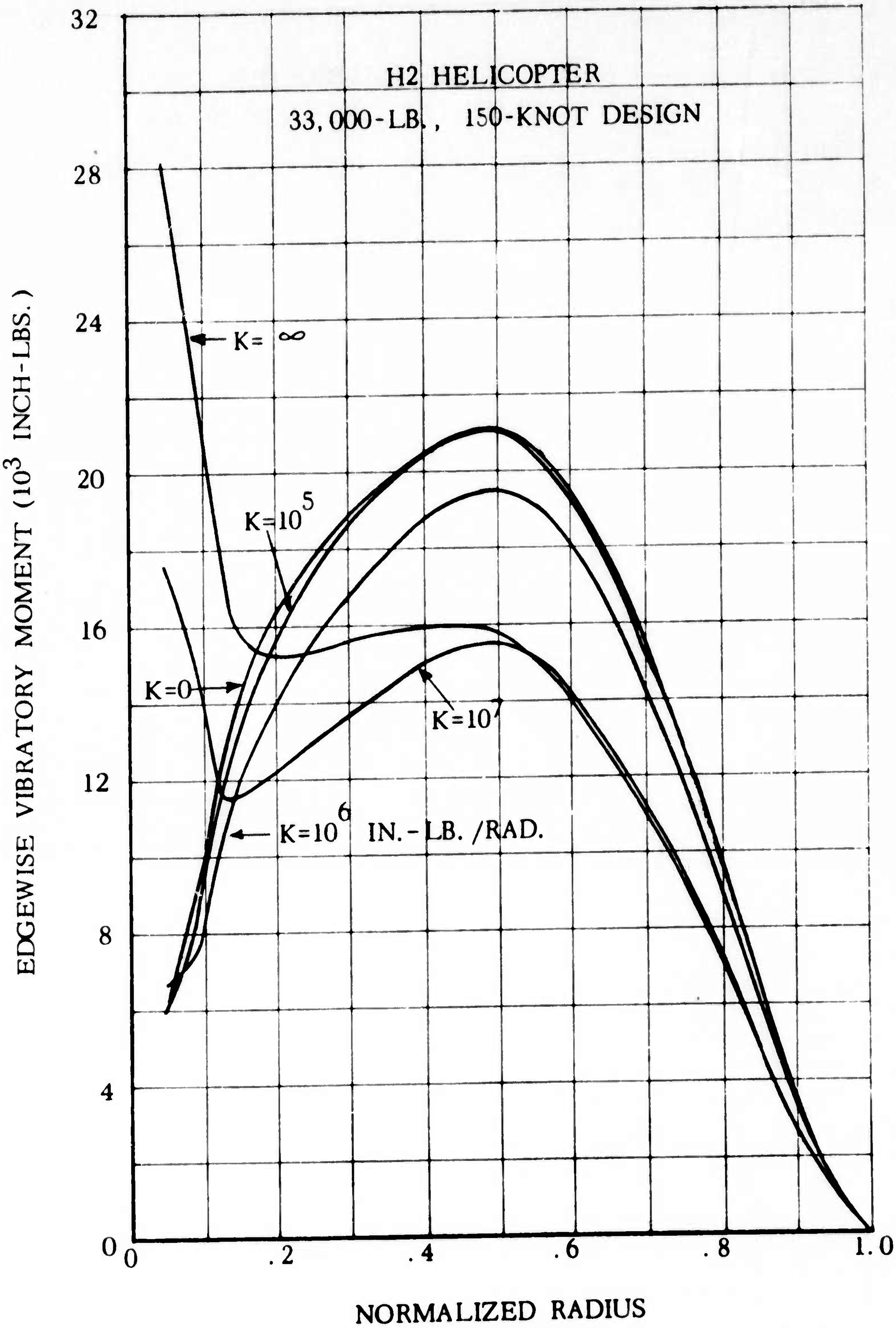


FIG. 11.11 EFFECT OF FLATWISE ROOT FLEXIBILITY ON EDGEWISE MOMENT

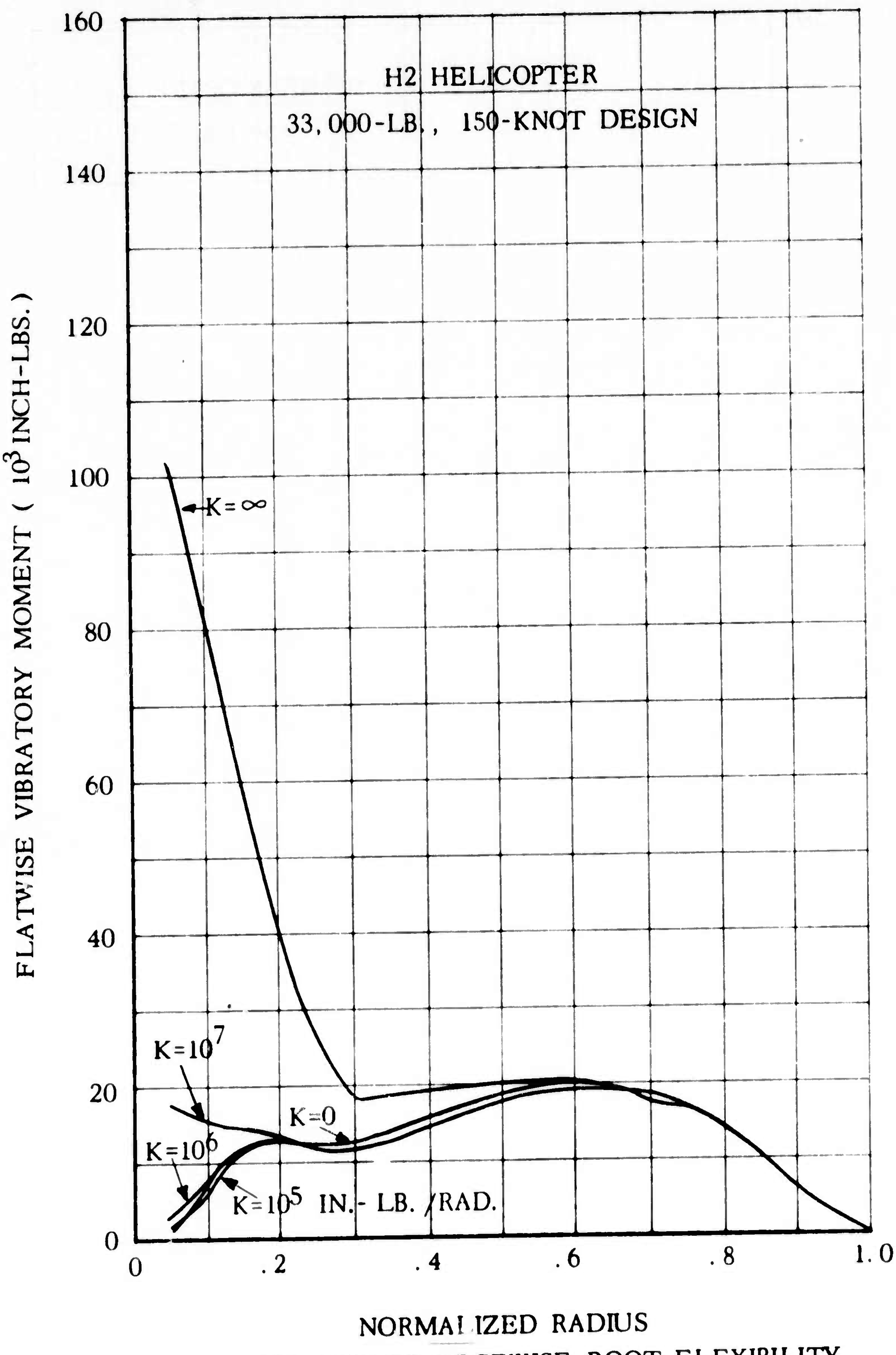


FIG. 11.12 EFFECT OF EDGEWISE ROOT FLEXIBILITY ON FLATWISE MOMENT

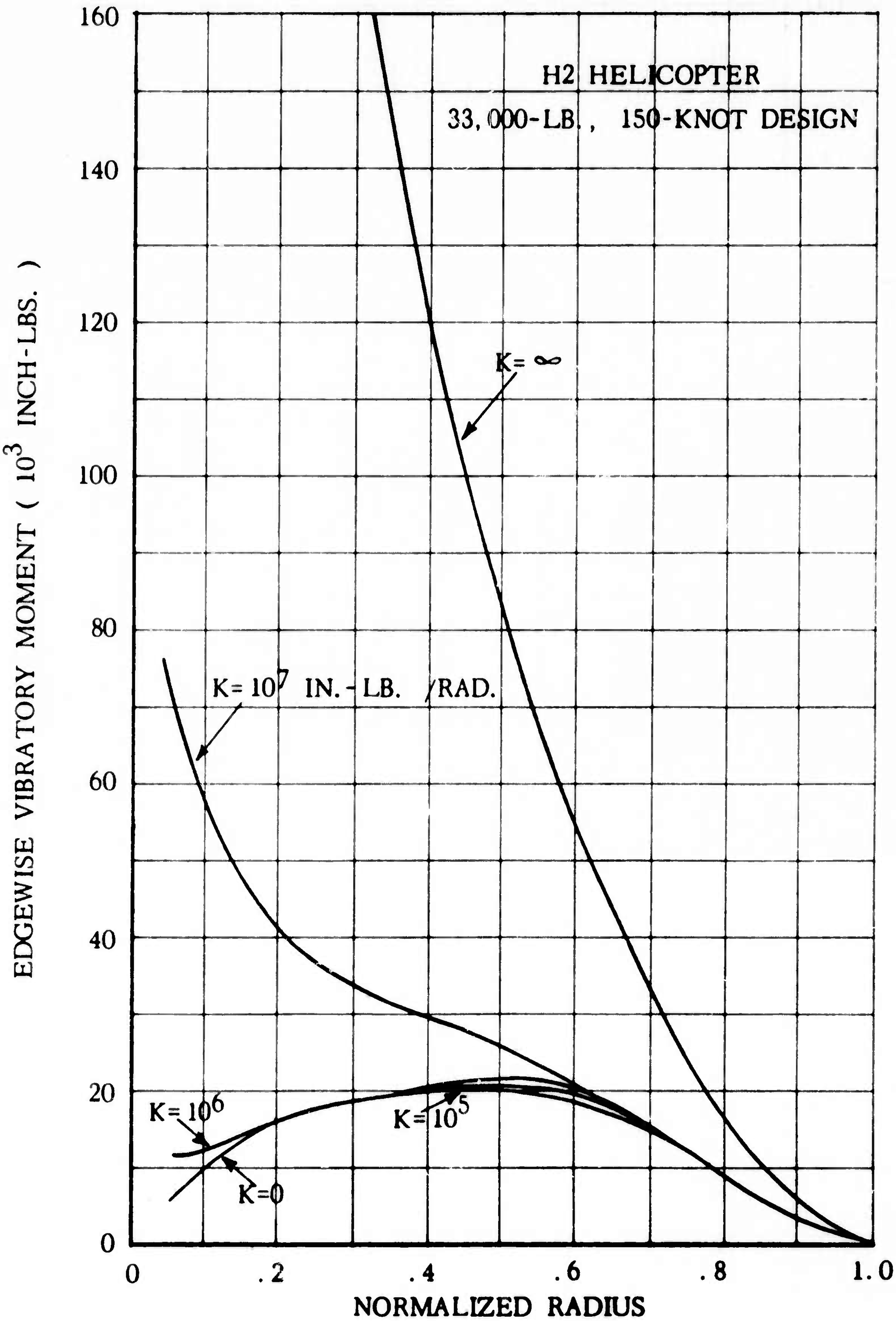


FIG. 11.13 EFFECT OF EDGEWISE ROOT FLEXIBILITY ON EDGEWISE MOMENT

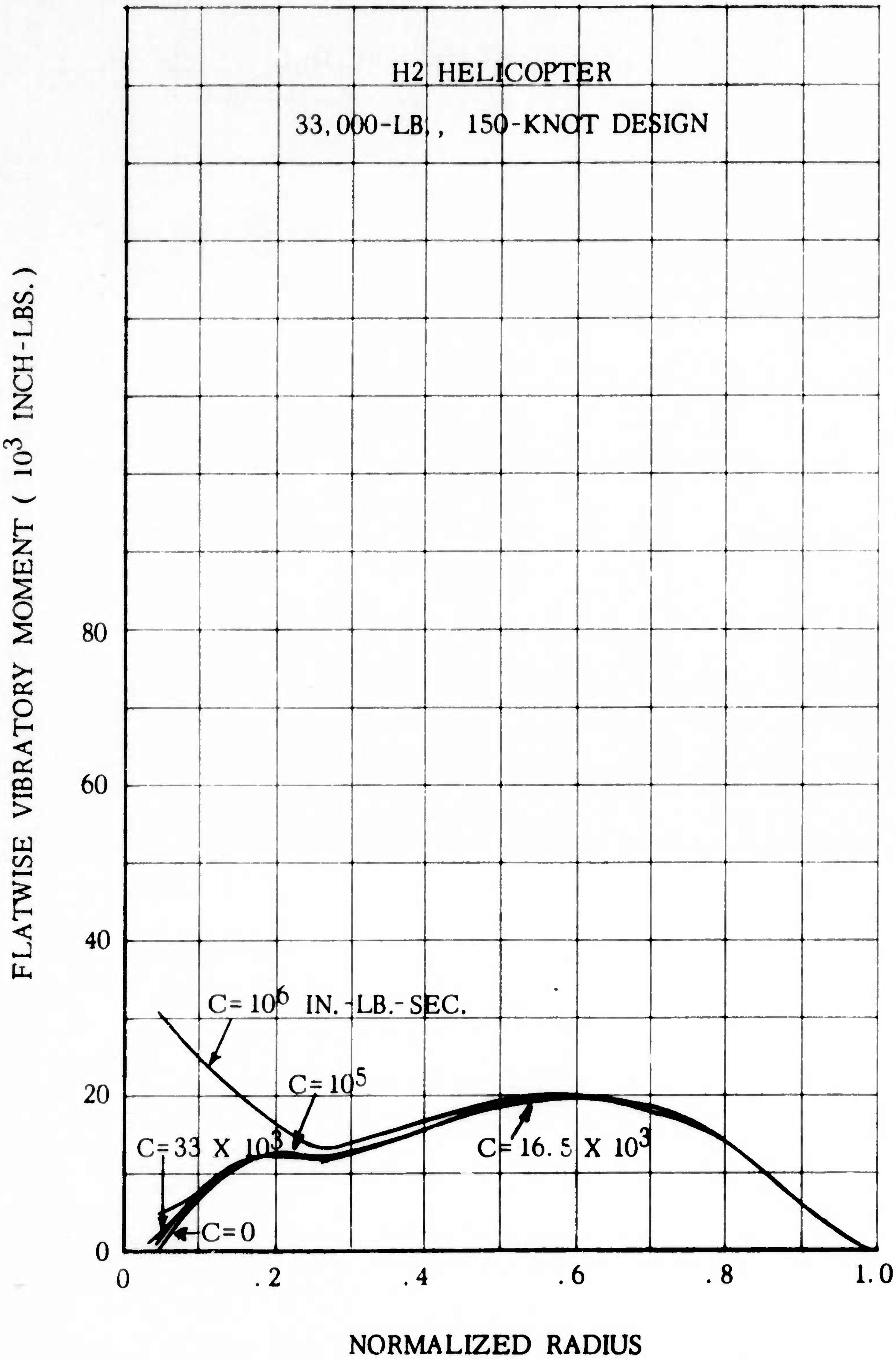


FIG. 11.14 EFFECT OF EDGEWISE DAMPER ON FLATWISE MOMENT

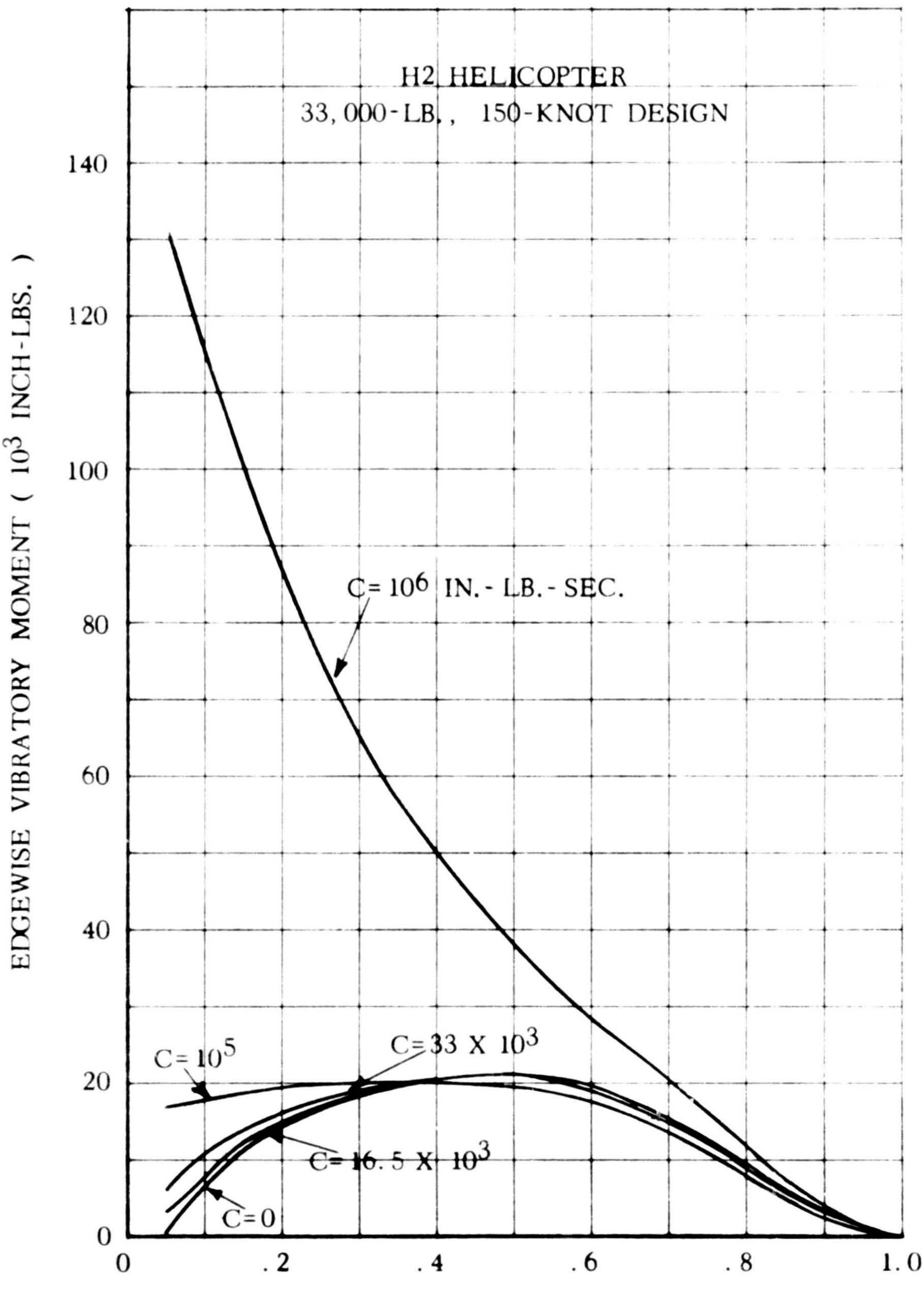
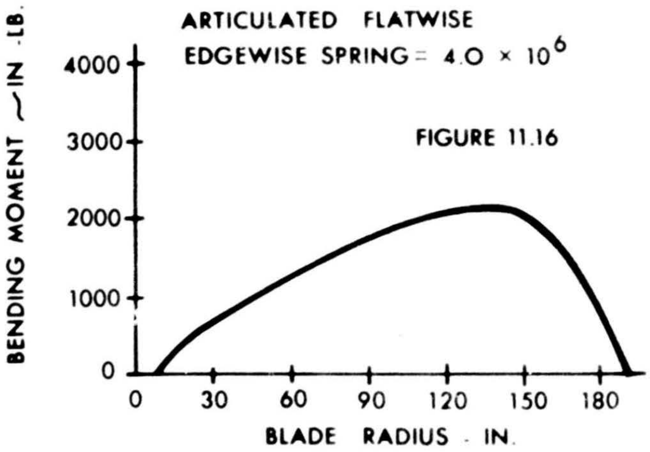


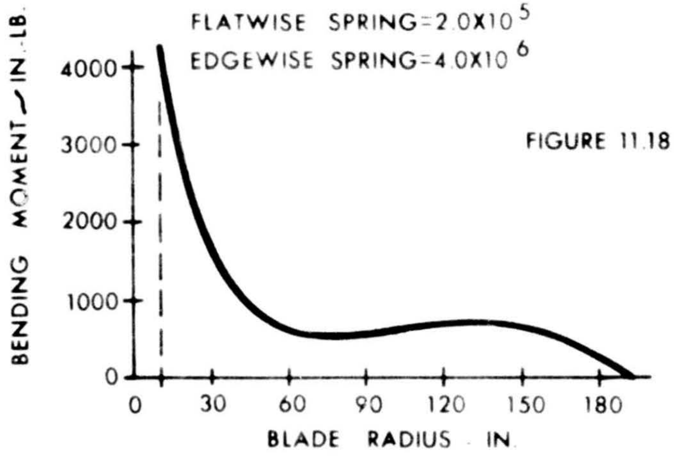
FIG. 11.15 EFFECT OF EDGEWISE DAMPER ON EDGEWISE MOMENT

EFFECT OF ROOT FLEXIBILITY ON BENDING MOMENTS AND STRESSES CALCULATED FOR LOCKHEED CL-475 HELICOPTER

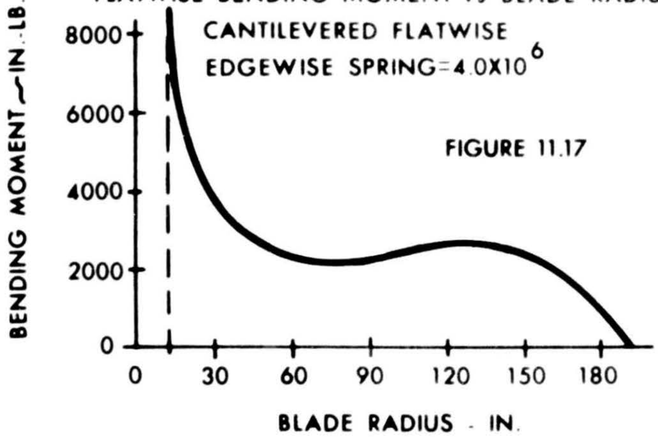
FLATWISE BENDING MOMENT VS. BLADE RADIUS



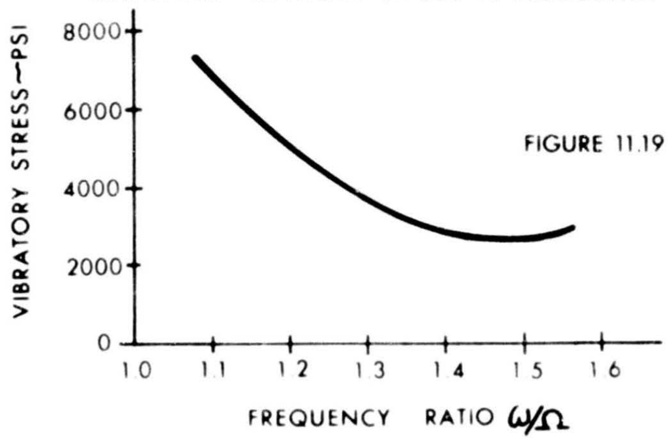
FLATWISE BENDING MOMENT vs BLADE RADIUS



FLATWISE BENDING MOMENT vs BLADE RADIUS



EDGEWISE VIBRATORY STRESS vs FREQUENCY RATIO



APPENDIX A

FUSELAGE LIFT AND DRAG DATA

ILLUSTRATIONS

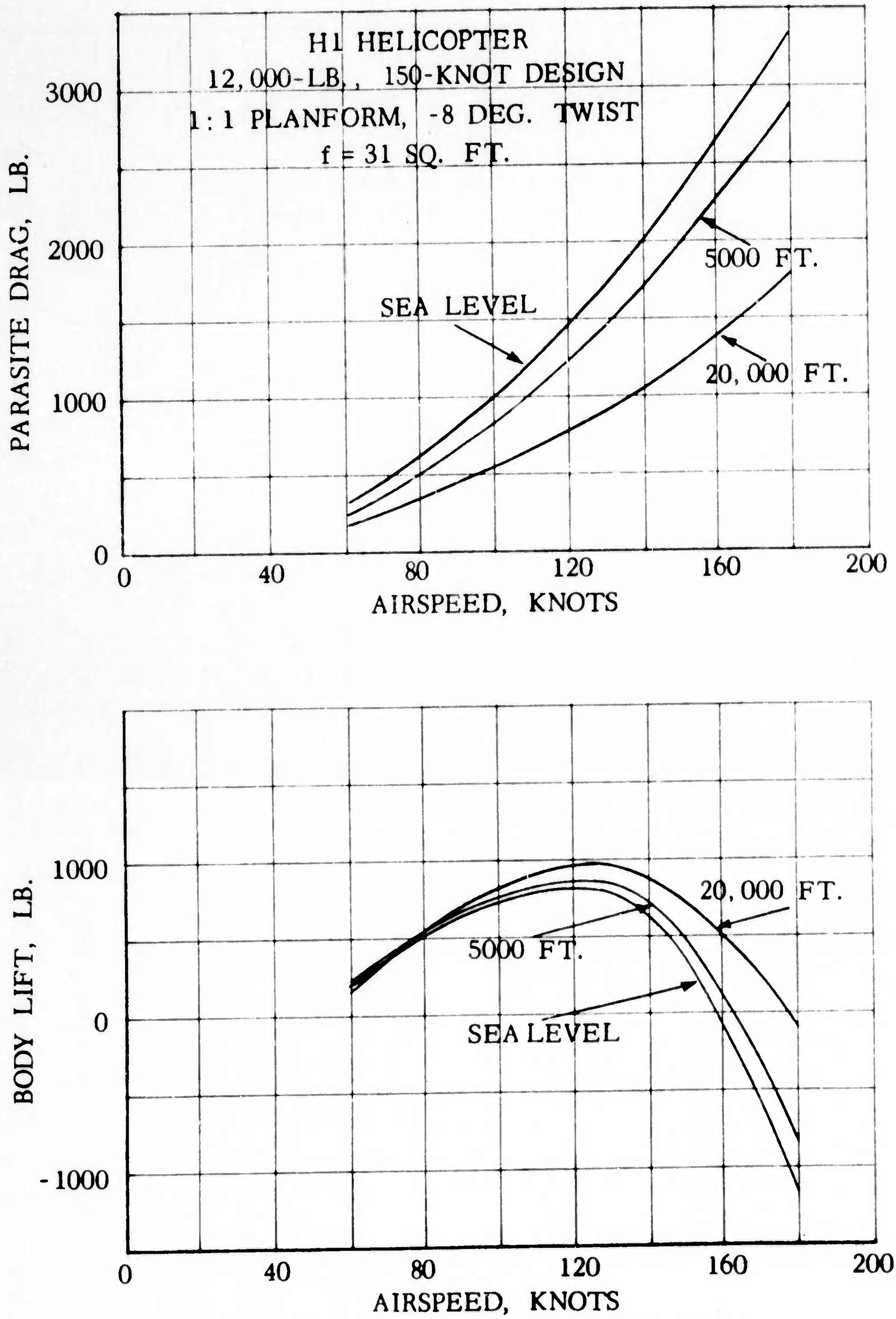
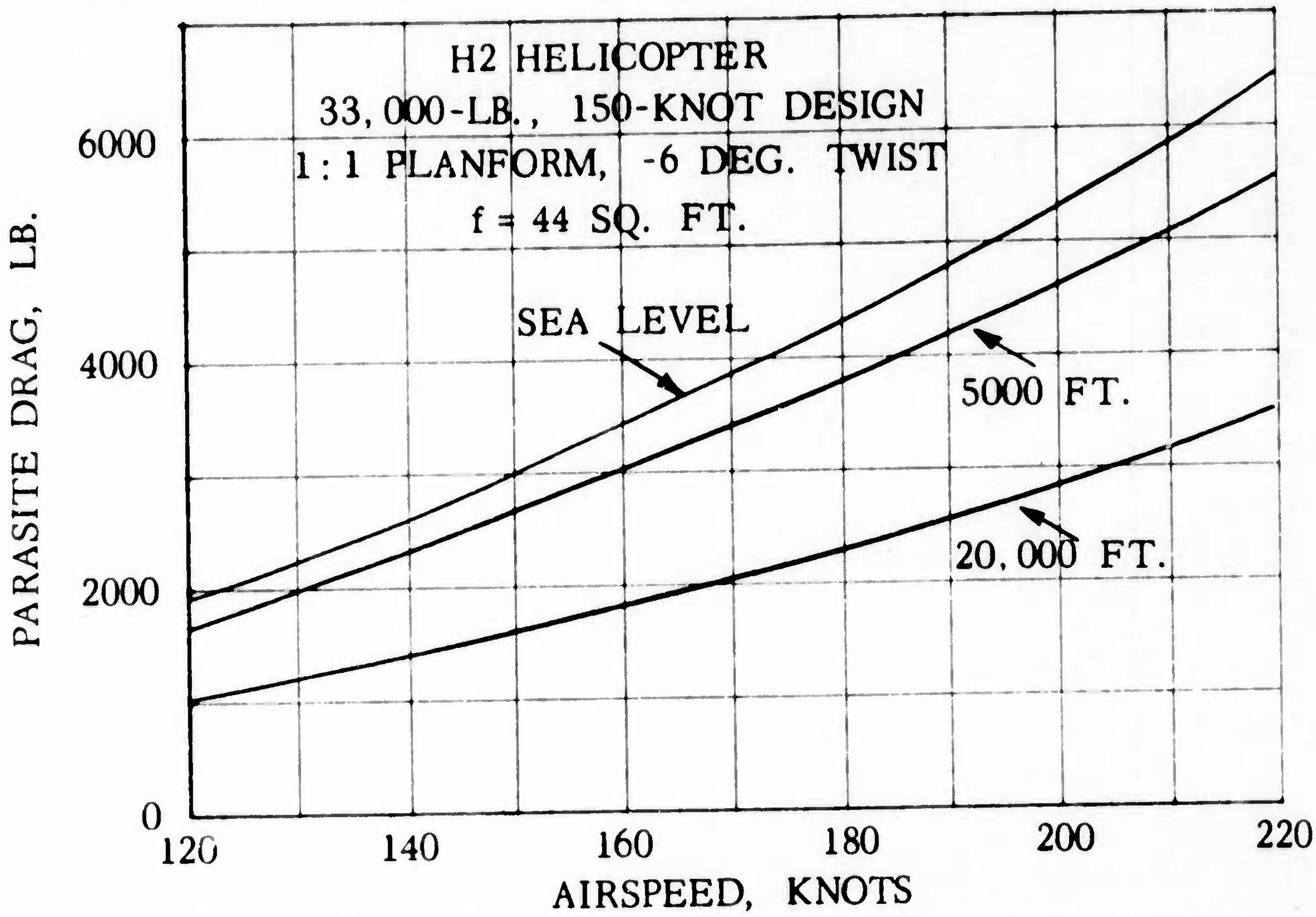


FIG. A-1 BODY LIFT AND DRAG DATA
FOR H1 HELICOPTER



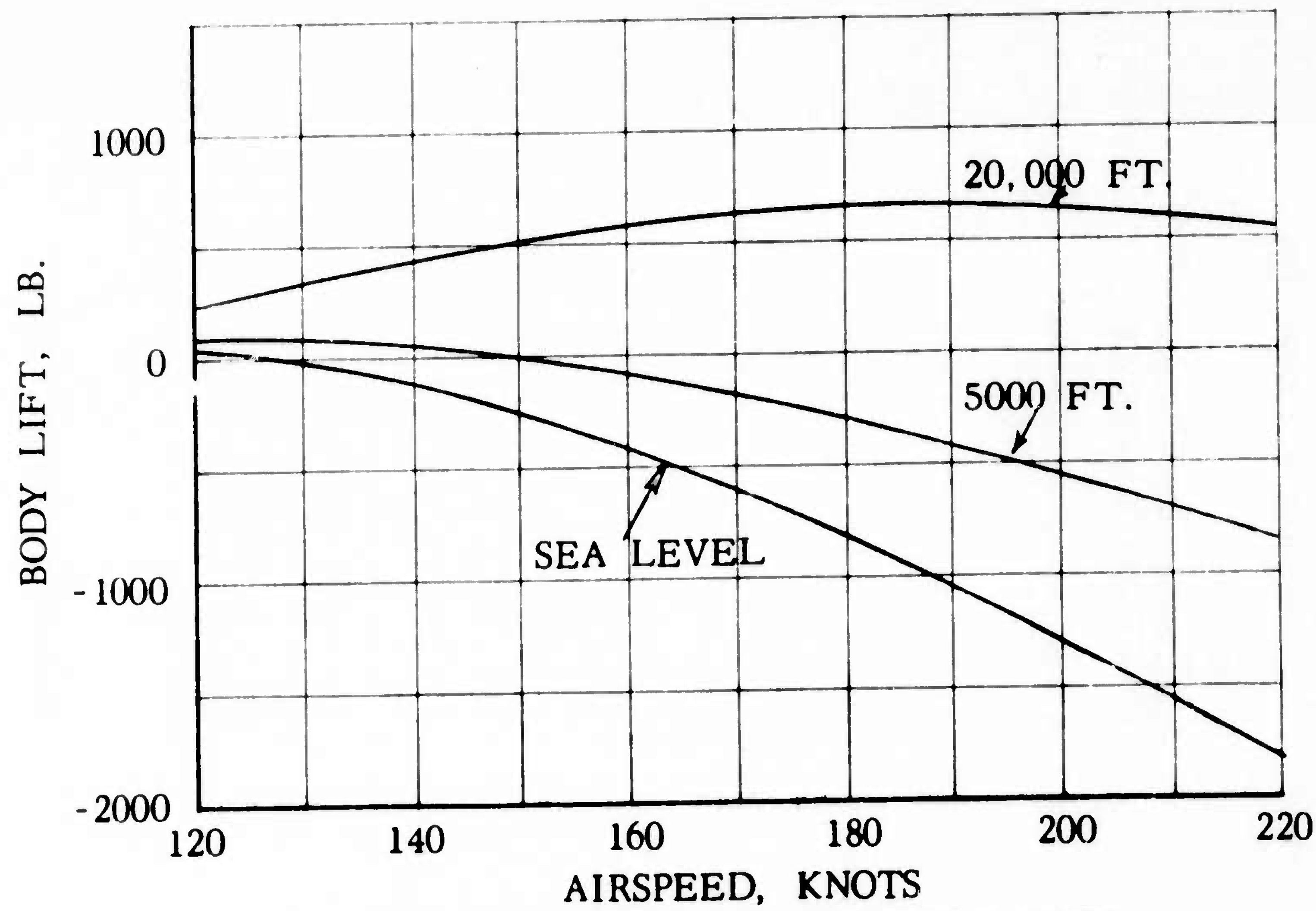
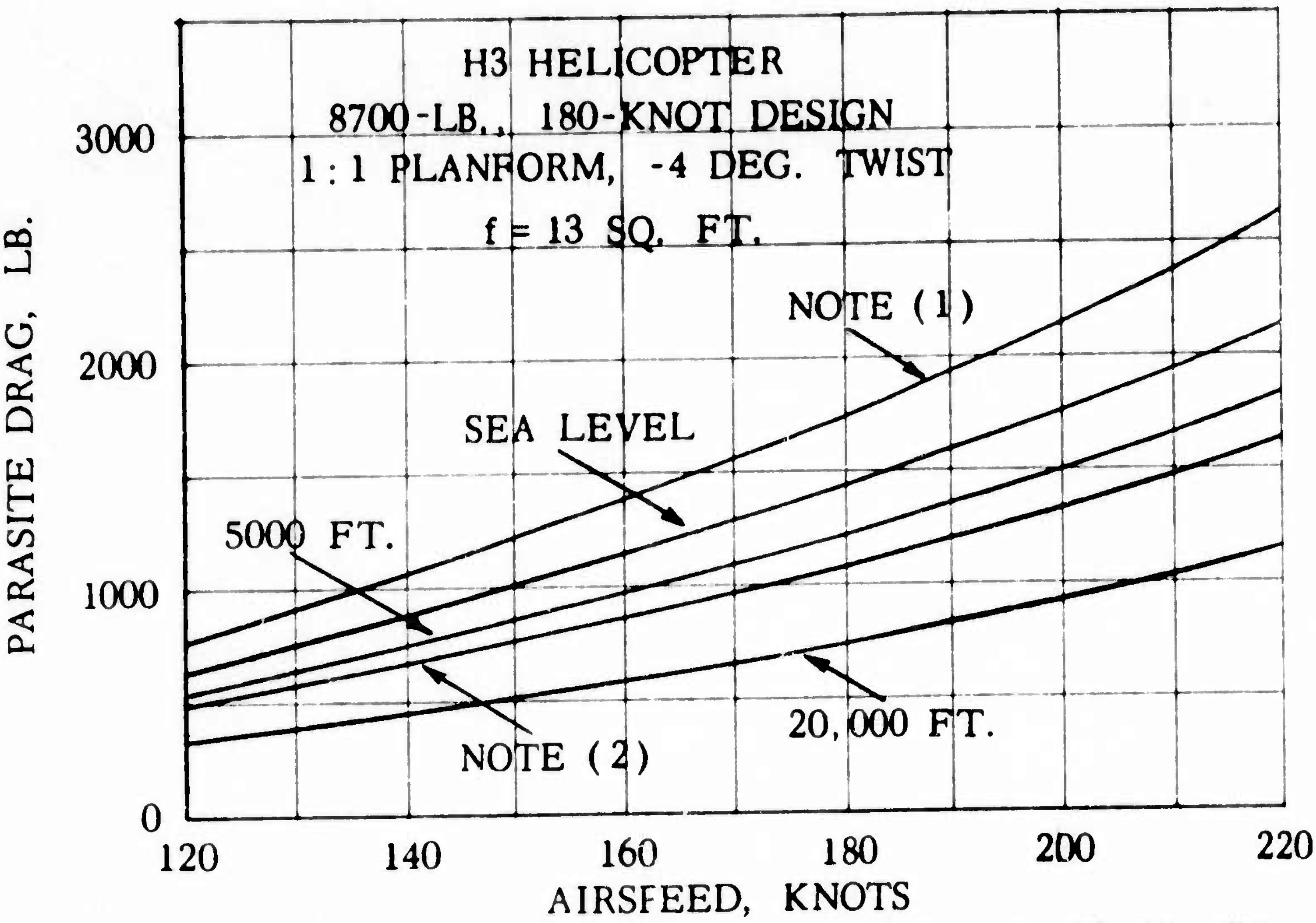


FIG. A-2 BODY LIFT AND DRAG DATA FOR H2 HELICOPTER



(1) S.L., f = 16 SQ. FT. (2) S.L., f = 10 SQ. FT.

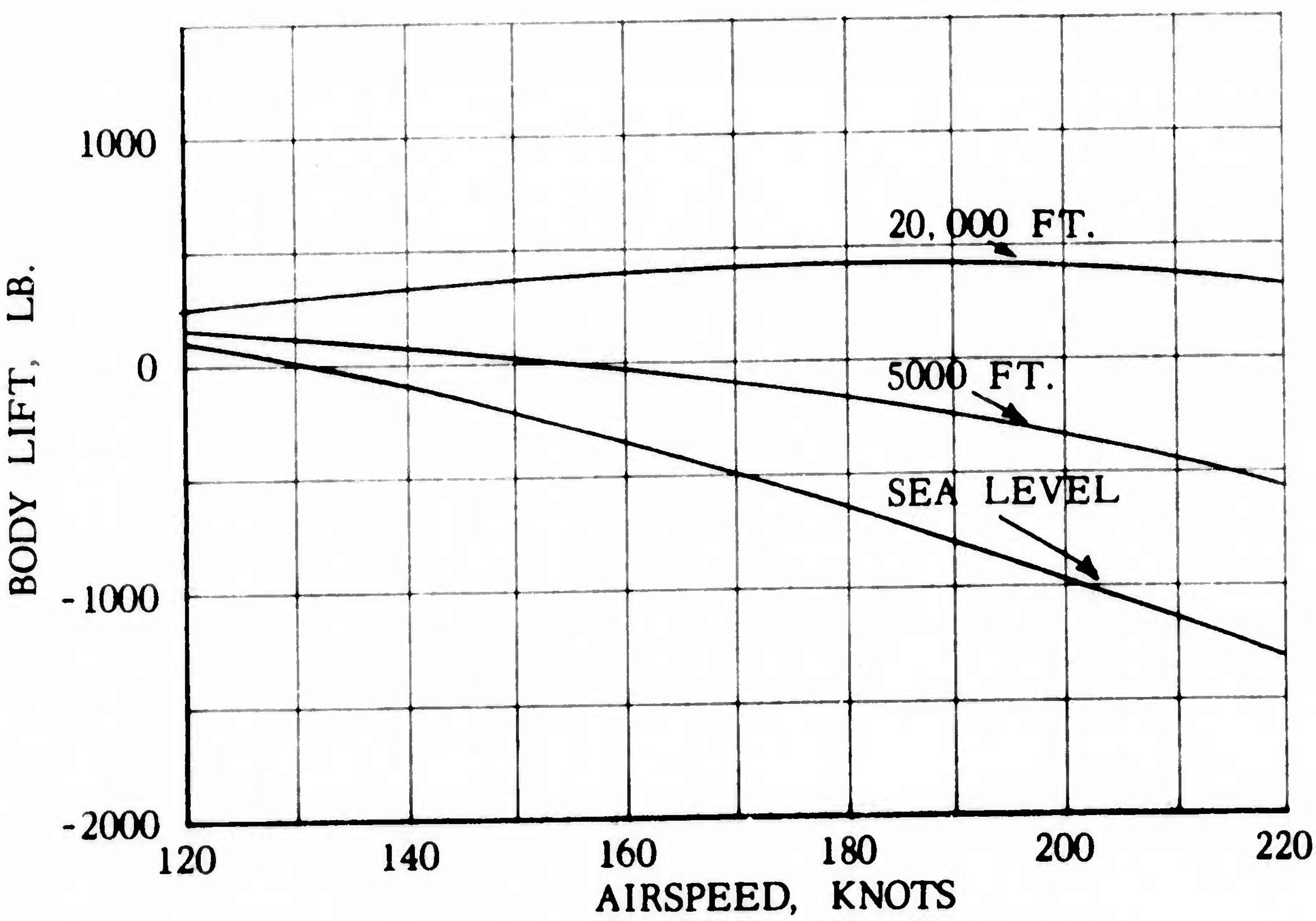
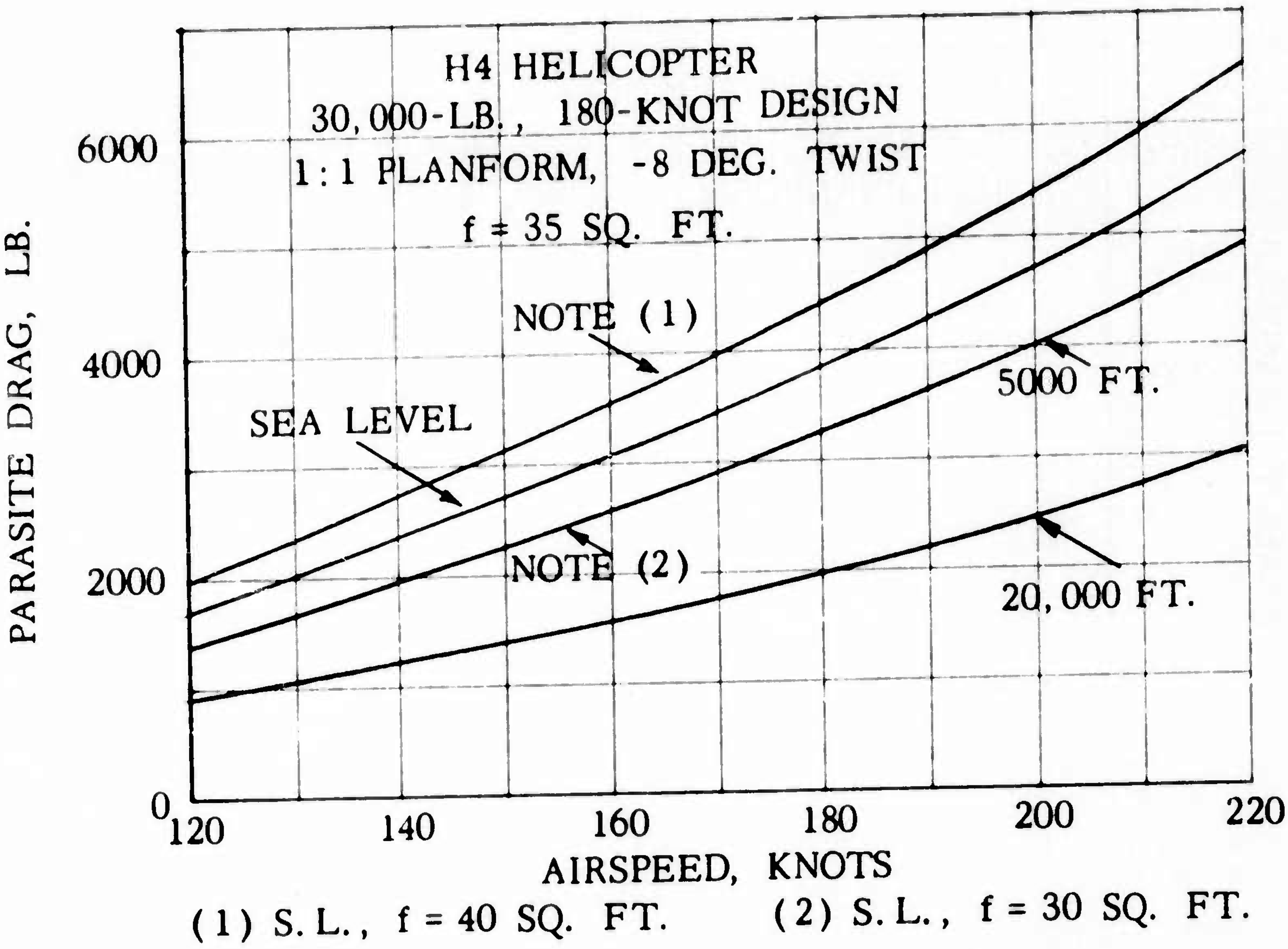


FIG. A-3 BODY LIFT AND DRAG DATA FOR H3 HELICOPTER



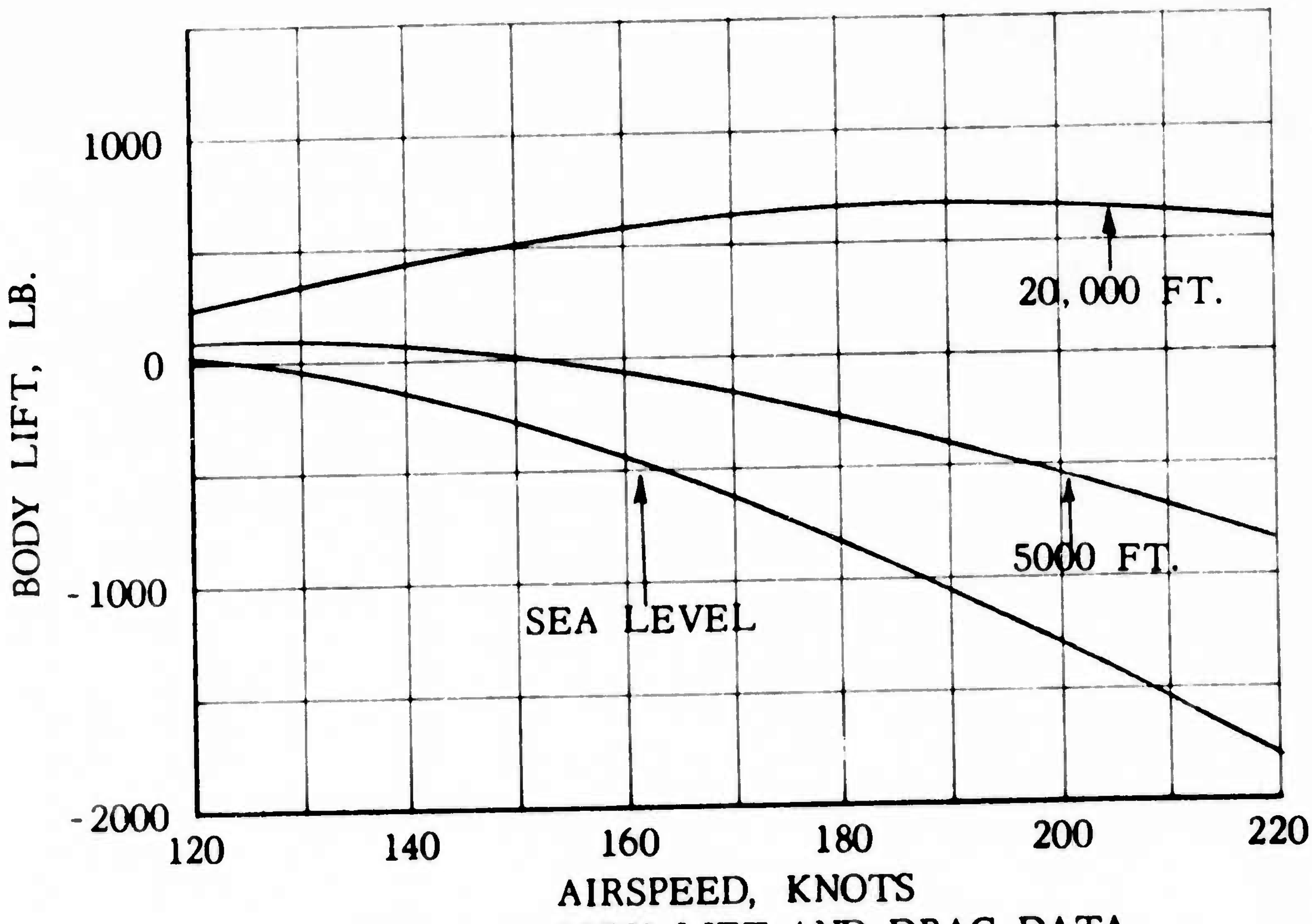


FIG. A-4 BODY LIFT AND DRAG DATA FOR H4 HELICOPTER

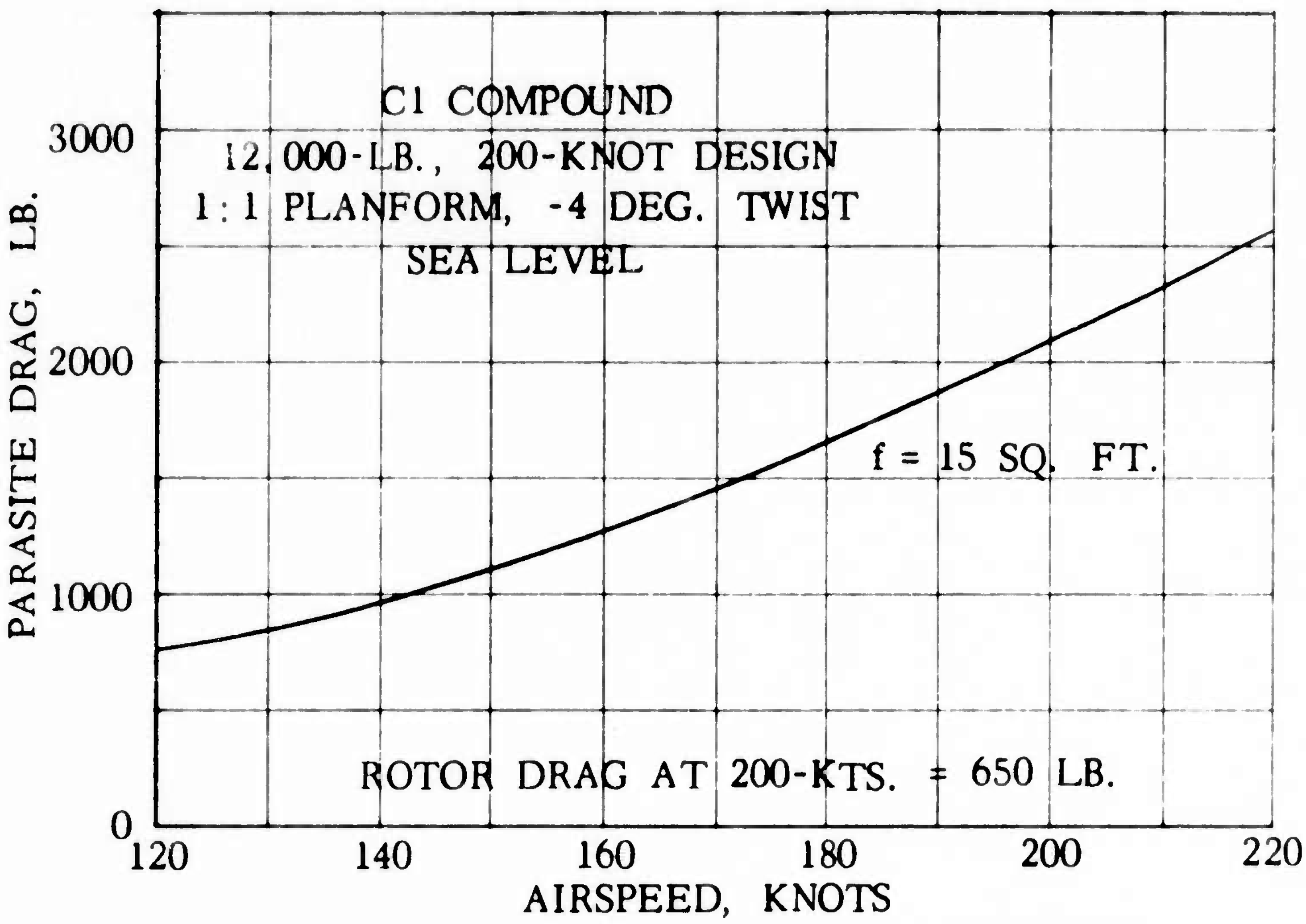


FIG. A-5 DRAG DATA FOR C1 COMPOUND

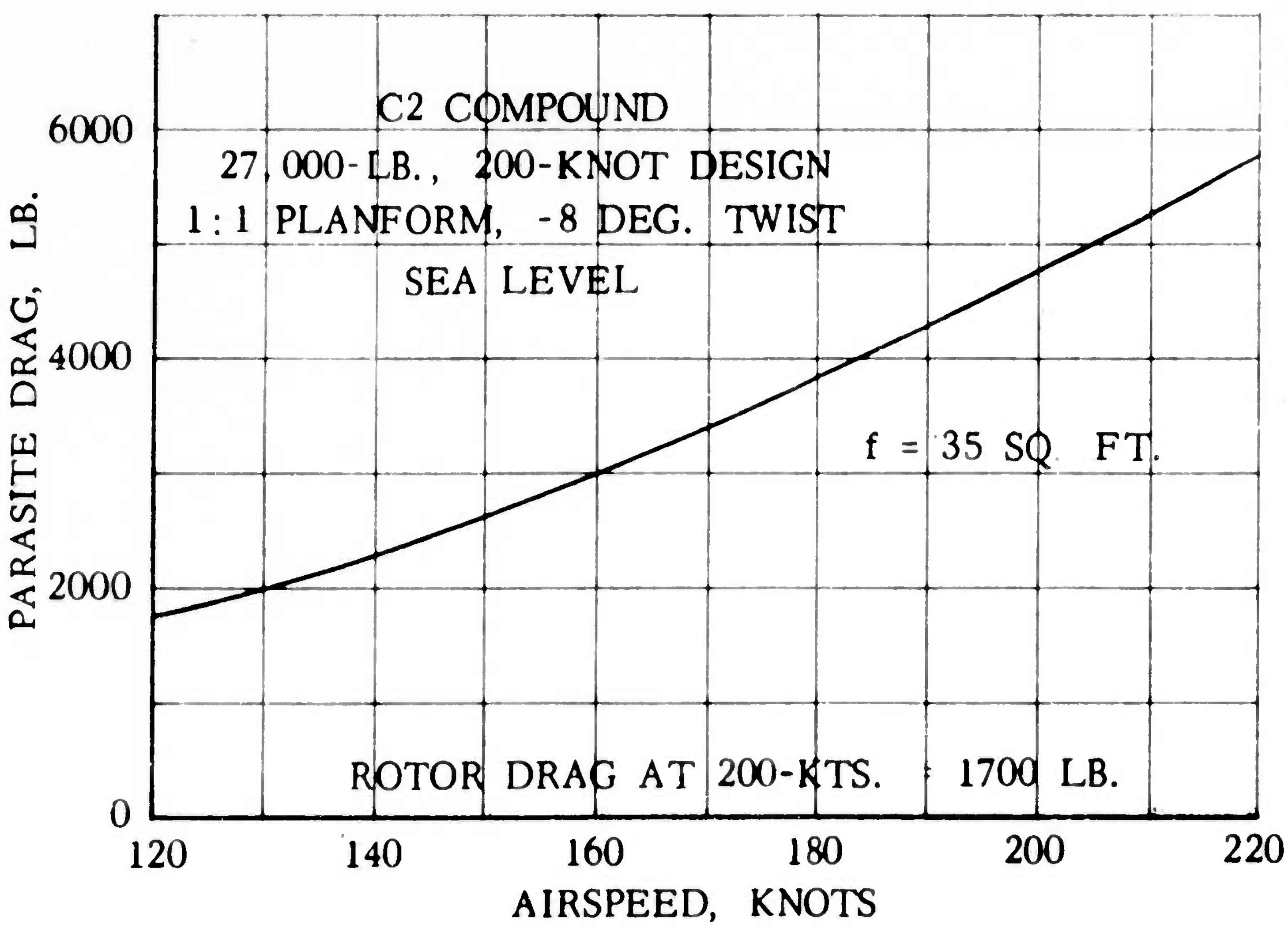


FIG. A-6 DRAG DATA FOR C2 COMPOUND

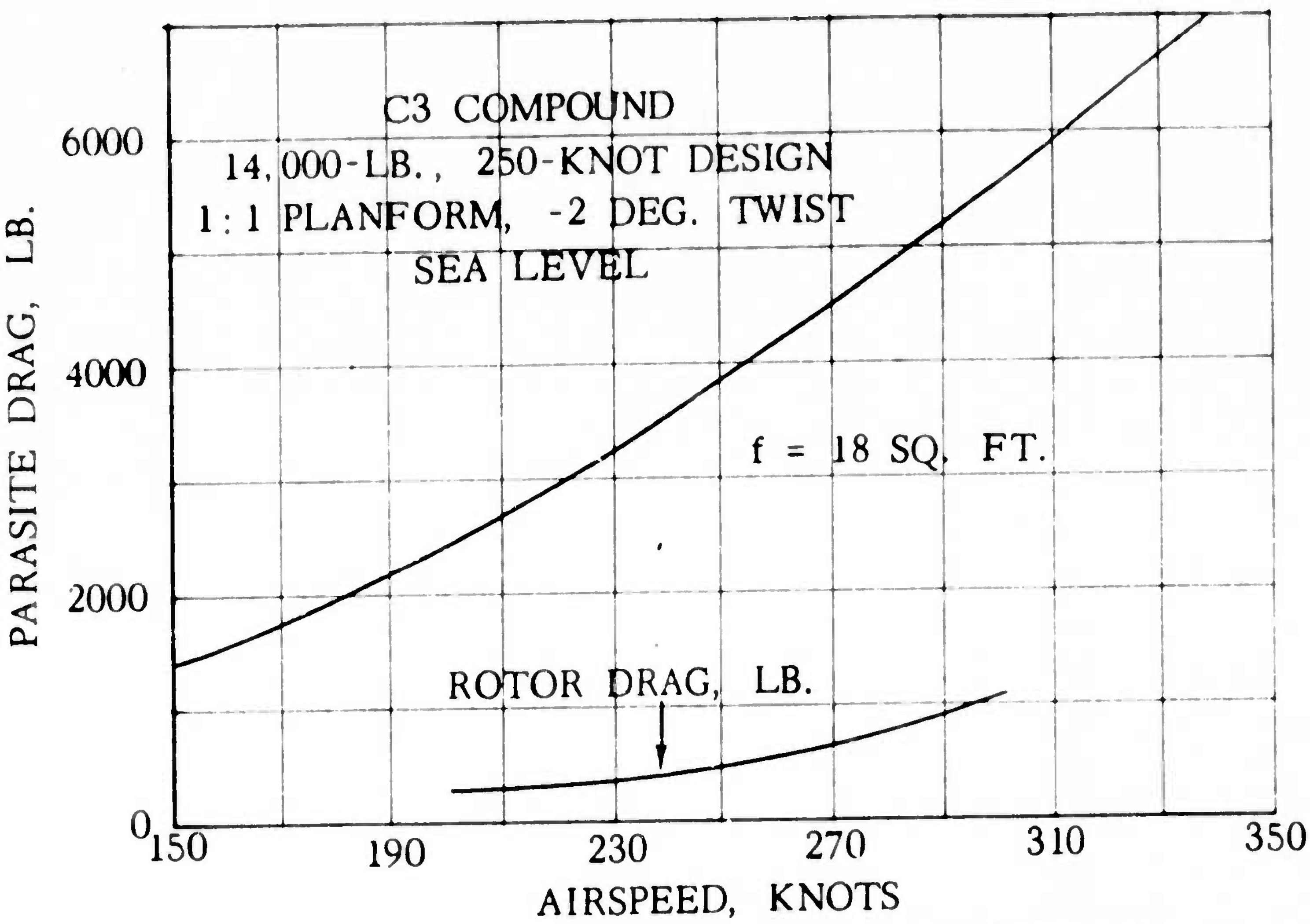


FIG. A-7 DRAG DATA FOR C3 COMPOUND

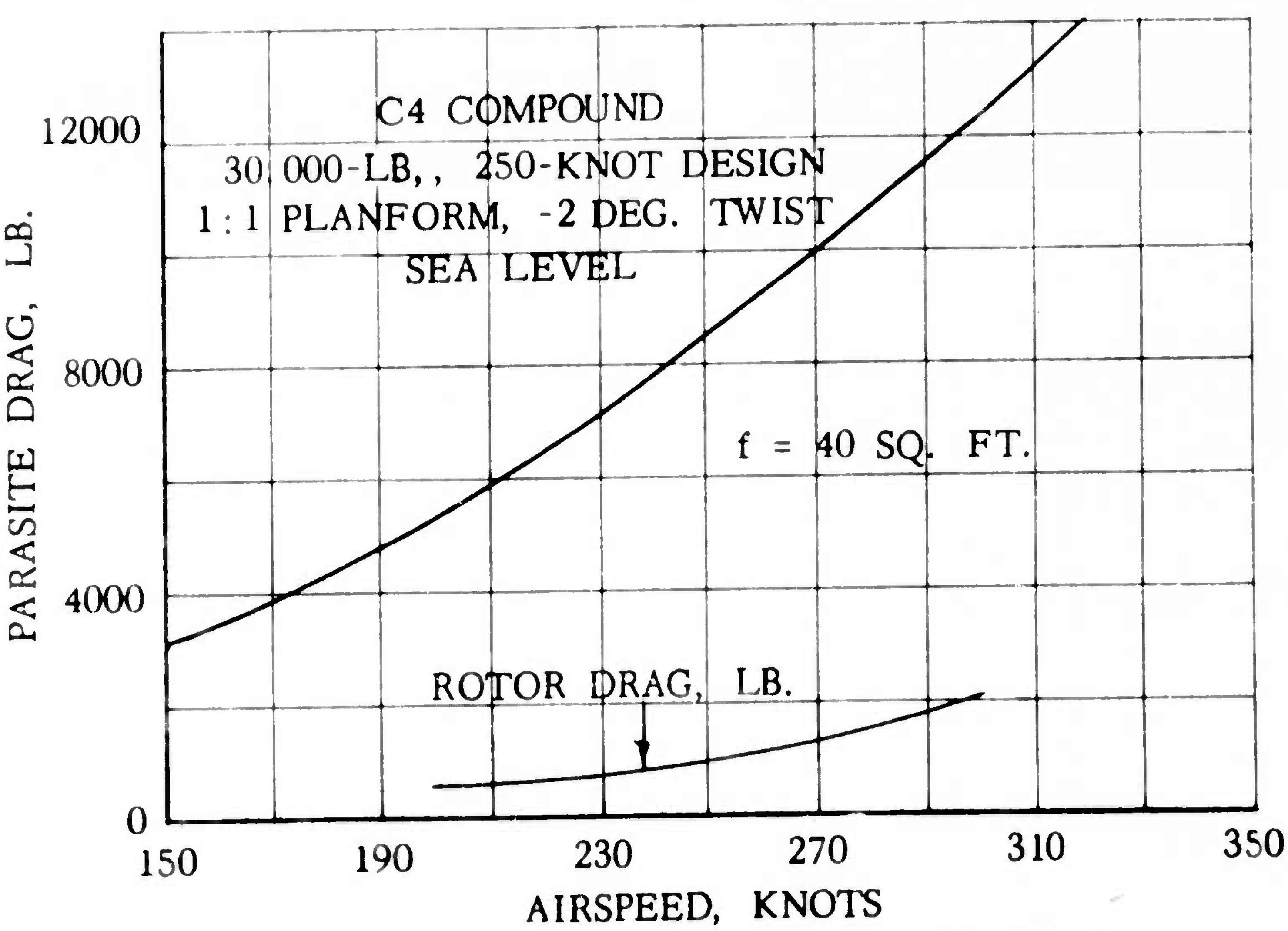


FIG. A-8 DRAG DATA FOR C4 COMPOUND

APPENDIX B

BLADE DATA

TABLES

TABLE B-1

BASIC BLADE DATA
H1 HELICOPTER
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	18.25	2.56	0.072	0.97	0.90	10.10	2.50	2.80	6.46
353.40	18.25	12.57	0.145	1.93	1.80	20.30	5.00	5.50	12.92
334.80	18.25	9.51	0.145	1.95	1.82	20.50	5.00	5.70	12.94
316.20	18.25	9.19	0.146	1.99	1.84	20.60	5.03	5.90	12.96
297.60	18.25	9.18	0.149	2.00	1.90	20.80	5.10	6.00	12.98
279.00	18.25	9.29	0.151	2.04	1.90	20.90	5.12	6.30	13.00
260.40	18.25	9.03	0.154	2.10	1.95	23.70	5.50	6.60	13.10
241.80	18.25	9.14	0.158	2.19	2.00	24.00	5.60	6.80	13.13
223.20	18.25	9.45	0.163	2.29	2.10	24.30	5.50	7.00	13.20
204.60	18.25	9.37	0.169	2.35	2.20	24.80	5.80	7.30	13.25
186.00	18.25	9.91	0.175	2.45	2.25	27.00	6.13	7.60	13.35
167.40	18.25	9.94	0.180	2.51	2.30	27.30	6.20	7.90	13.38
148.80	18.25	10.01	0.186	2.60	2.36	28.00	6.27	8.20	13.40
130.20	18.25	9.73	0.191	2.71	2.40	28.50	6.40	8.50	13.47
111.60	18.25	8.78	0.196	2.80	2.50	29.30	6.58	9.00	13.52
93.00	18.25	9.06	0.202	2.91	2.60	29.80	6.70	9.90	13.58
74.40	8.10	8.53	0.210	3.04	2.70	30.50	6.92	14.00	13.68
55.80	8.10	10.51	0.265	4.40	3.60	35.00	7.95	30.00	14.10
37.20	8.10	55.21	1.000	45.00	14.00	70.00	10.00	50.00	50.00
18.60	8.10	84.17	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	20.46	2.000	75.00	18.00	75.00	15.00	100.00	100.00

DESIGN TWIST -8 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-2

BASIC BLADE DATA
H1 HELICOPTER
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	6.08	2.56	0.164	0.12	0.22	1.86	0.89	0.48	1.26
353.40	9.12	12.57	0.329	0.24	0.44	3.72	1.78	0.96	2.52
334.80	12.16	9.51	0.228	0.68	0.94	8.13	2.87	2.20	5.65
316.20	15.20	9.19	0.178	1.28	1.40	13.76	3.86	3.90	9.68
297.60	18.25	9.18	0.149	2.00	1.90	20.80	5.10	6.00	12.98
279.00	18.25	9.29	0.151	2.04	1.90	20.90	5.12	6.30	13.00
260.40	18.25	9.03	0.154	2.10	1.95	23.70	5.50	6.60	13.10
241.80	18.25	9.14	0.158	2.19	2.00	24.00	5.60	6.80	13.13
223.20	18.25	9.45	0.163	2.29	2.10	24.30	5.50	7.00	13.20
204.60	18.25	9.37	0.169	2.35	2.20	24.80	5.80	7.30	13.25
186.00	18.25	9.91	0.175	2.45	2.25	27.00	6.13	7.60	13.35
167.40	18.25	9.94	0.180	2.51	2.30	27.30	6.20	7.90	13.38
148.80	18.25	10.01	0.186	2.60	2.36	28.00	6.27	8.20	13.40
130.20	18.25	9.73	0.191	2.71	2.40	28.50	6.40	8.50	13.47
111.60	18.25	8.78	0.196	2.80	2.50	29.30	6.58	9.00	13.52
93.00	18.25	9.06	0.202	2.91	2.60	29.80	6.70	9.90	13.58
74.40	8.10	8.53	0.210	3.04	2.70	30.50	6.92	14.00	13.68
55.80	8.10	10.51	0.265	4.40	3.60	35.00	7.95	30.00	14.10
37.20	8.10	55.21	1.000	45.00	14.00	70.00	10.00	50.00	50.00
18.60	8.10	84.17	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	20.46	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-3

BASIC BLADE DATA
H1 HELICOPTER
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	12.20	2.56	0.100	0.45	0.56	5.17	1.64	1.40	3.67
353.40	13.50	12.57	0.200	0.91	1.12	10.34	3.29	2.78	7.34
334.80	14.70	9.51	0.180	1.16	1.31	12.80	3.71	3.50	9.04
316.20	16.00	9.19	0.170	1.45	1.51	15.43	4.11	4.38	10.89
297.60	17.20	9.18	0.160	1.74	1.68	18.28	4.53	5.25	12.81
279.00	18.40	9.29	0.150	2.11	1.89	21.53	4.93	6.29	15.05
260.40	19.50	9.03	0.140	2.45	2.10	27.36	5.82	7.54	16.83
241.80	20.80	9.14	0.140	2.94	2.37	31.52	6.29	9.00	19.11
223.20	22.00	9.45	0.130	3.54	2.68	36.37	6.81	10.45	21.77
204.60	23.20	9.37	0.130	4.10	2.95	41.61	7.42	12.26	24.34
186.00	24.40	9.91	0.130	4.82	3.29	50.53	8.44	14.29	27.02
167.40	25.60	9.94	0.130	5.54	3.60	57.04	9.05	16.63	30.16
148.80	26.80	10.01	0.120	6.27	3.91	63.47	9.78	18.78	32.67
130.20	28.00	9.73	0.120	7.43	4.42	73.13	10.70	22.09	36.03
111.60	29.20	8.78	0.120	8.58	4.89	83.53	11.81	25.46	39.28
93.00	30.40	9.06	0.120	9.94	5.43	94.14	12.68	30.23	42.95
74.40	14.10	8.53	0.120	11.59	6.07	106.90	13.79	34.33	46.79
55.80	14.70	10.51	0.140	17.75	8.99	126.62	15.88	51.35	49.92
37.20	14.70	55.21	1.000	45.00	14.00	70.00	10.00	50.00	50.00
18.60	14.70	84.17	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	14.70	20.46	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-4

BASIC BLADE DATA
H1 HELICOPTER
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	21.00	2.56	0.065	1.25	1.02	12.90	2.70	3.58	9.36
353.40	20.40	12.57	0.129	2.50	2.04	25.80	5.40	7.16	18.72
334.80	19.80	9.51	0.133	2.35	1.98	24.43	5.25	6.83	17.53
316.20	19.30	9.19	0.138	2.27	1.96	23.24	5.12	6.68	16.56
297.60	18.80	9.18	0.144	2.14	1.90	22.18	5.02	6.41	15.61
279.00	18.40	9.29	0.150	2.08	1.88	21.27	4.90	6.21	14.87
260.40	17.80	9.03	0.158	1.98	1.85	22.44	5.23	6.14	13.74
241.80	17.30	9.14	0.167	1.92	1.85	21.34	5.11	6.02	12.83
223.20	16.70	9.45	0.180	1.84	1.84	19.96	4.94	5.63	11.79
204.60	16.20	9.37	0.192	1.75	1.80	19.01	4.87	5.46	10.93
186.00	15.70	9.91	0.207	1.67	1.77	19.22	5.02	5.27	10.05
167.40	15.20	9.94	0.221	1.57	1.72	18.01	4.86	5.06	9.27
148.80	14.60	10.01	0.239	1.45	1.65	16.77	4.76	4.75	8.36
130.20	14.10	9.73	0.256	1.36	1.60	15.66	4.59	4.50	7.61
111.60	13.60	8.78	0.275	1.25	1.53	14.68	4.50	4.23	6.88
93.00	13.00	9.06	0.300	1.11	1.42	13.24	4.23	3.98	6.03
74.40	5.50	8.53	0.328	1.00	1.33	12.15	4.04	3.63	5.35
55.80	5.50	10.51	0.447	1.06	1.47	11.67	4.12	4.83	4.27
37.20	5.00	55.21	1.000	45.00	14.00	70.00	10.00	50.00	50.00
18.60	5.00	84.17	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	5.00	20.46	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-5

BASIC BLADE DATA
H2 HELICOPTER
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	23.65	6.97	0.081	1.87	1.38	19.90	3.80	5.90	9.55
410.40	23.65	19.60	0.162	3.75	2.92	39.80	7.80	12.70	19.20
388.80	23.65	14.51	0.183	4.20	3.24	42.90	8.50	15.00	19.40
367.20	23.65	15.77	0.204	4.75	3.62	53.00	9.80	14.90	19.73
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	24.10	13.20	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	9.71	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	9.71	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

DESIGN TWIST -6 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-6

BASIC BLADE DATA
H2 HELICOPTER
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	7.88	6.97	0.180	0.27	0.39	3.83	1.59	1.10	2.13
410.40	11.82	19.60	0.361	0.55	0.78	7.66	3.19	2.20	4.27
388.80	15.76	14.51	0.287	1.51	1.60	17.13	5.30	5.34	8.98
367.20	19.70	15.77	0.249	3.03	2.56	35.24	8.24	10.60	14.90
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	24.10	13.20	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	9.71	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	9.71	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-7

BASIC BLADE DATA
H2 HELICOPTER
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX (IN.^{4})	SEC-TION ZXX (IN.^{3})	EDGE-WISE IYY (IN.^{4})	SEC-TION ZYY (IN.^{3})	TOR-SION J (IN.^{4})	MID-LINE AREA (IN.^{2})
432.00	15.80	6.97	0.113	0.89	0.86	10.11	2.82	2.95	5.80
410.40	17.40	19.60	0.226	1.79	1.72	20.22	5.64	5.90	11.61
388.80	18.90	14.51	0.232	2.48	2.18	26.48	6.77	8.36	14.06
367.20	20.50	15.77	0.239	3.35	2.73	38.58	8.66	11.63	16.35
345.60	22.00	15.74	0.229	4.24	3.21	47.11	9.92	14.43	19.10
324.00	23.70	17.14	0.216	5.45	3.83	65.10	12.45	19.09	22.37
302.40	25.30	10.29	0.204	6.62	4.35	76.43	13.63	22.44	26.07
280.80	26.80	17.63	0.196	7.66	4.76	86.88	14.70	25.83	29.29
259.20	28.50	17.02	0.194	8.30	5.03	92.99	15.35	27.91	31.00
237.60	30.00	18.04	0.180	10.40	5.78	113.00	17.07	34.13	37.43
216.00	31.60	17.71	0.173	11.90	6.28	127.60	18.35	39.16	41.84
194.40	33.20	16.61	0.167	13.65	6.84	143.90	19.67	44.39	46.60
172.80	34.70	16.42	0.164	14.84	7.20	155.30	20.58	48.29	49.93
151.20	36.40	16.42	0.157	17.31	7.93	177.70	22.23	56.03	56.39
129.60	37.90	17.33	0.155	19.25	8.44	200.20	23.82	62.41	61.65
108.00	16.20	18.46	0.167	26.92	11.36	246.50	28.26	77.42	66.44
86.40	16.90	38.11	0.193	117.70	46.59	486.30	54.83	294.40	72.42
64.80	16.90	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	16.90	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	16.90	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-8

BASIC BLADE DATA
H2 HELICOPTER
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	27.00	6.97	0.072	2.40	1.51	25.14	4.59	7.48	14.68
410.40	26.40	19.60	0.144	4.80	3.03	50.29	9.19	14.97	29.36
388.80	25.70	14.51	0.168	5.08	3.29	51.26	9.65	16.43	27.54
367.20	25.00	15.77	0.192	5.41	3.61	59.81	10.98	18.21	25.57
345.60	24.40	15.74	0.205	5.44	3.71	59.22	11.22	18.23	24.11
324.00	23.60	17.14	0.217	5.39	3.81	64.50	12.38	18.91	22.16
302.40	22.90	10.29	0.228	5.16	3.75	60.77	12.04	17.74	20.63
280.80	22.30	17.63	0.239	4.91	3.67	57.84	11.79	17.03	19.34
259.20	21.60	17.02	0.252	4.62	3.57	54.45	11.48	16.13	17.95
237.60	21.00	18.04	0.265	4.40	3.50	51.39	11.15	15.24	16.76
216.00	20.30	17.71	0.281	4.09	3.36	47.98	10.81	14.40	15.43
194.40	19.60	16.61	0.297	3.79	3.22	44.63	10.42	13.40	14.11
172.80	18.90	16.42	0.316	3.46	3.05	41.18	10.00	12.42	12.88
151.20	18.20	16.42	0.336	3.16	2.89	37.89	9.58	11.54	11.64
129.60	17.50	17.33	0.365	2.80	2.66	35.11	9.18	10.53	10.42
108.00	7.00	18.46	0.434	2.97	2.93	35.09	9.55	10.59	90.37
86.40	6.70	38.11	0.710	3.50	3.60	28.04	8.69	23.93	44.19
64.80	6.70	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	6.70	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	6.70	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-9

BASIC BLADE DATA
H3 HELICOPTER
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	18.25	2.27	0.072	0.98	0.92	10.30	2.50	2.90	12.94
319.20	18.25	10.99	0.146	1.96	1.84	20.50	5.00	5.90	12.94
302.40	18.25	8.88	0.148	2.00	1.88	20.70	5.10	6.02	12.98
285.60	18.25	8.40	0.151	2.02	1.90	20.90	5.10	6.15	13.00
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.31	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.213	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	6.80	5.00	37.80	8.60	20.00	14.85
33.60	8.10	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	8.10	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

DESIGN TWIST -4 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-10

BASIC BLADE DATA
H3 HELICOPTER
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	6.08	2.27	0.161	0.12	0.22	1.87	0.89	0.49	1.25
319.20	9.12	10.99	0.332	0.24	0.44	3.73	1.77	0.99	2.50
302.40	12.16	8.88	0.233	0.69	0.95	8.19	2.89	2.29	5.62
285.60	15.20	8.40	0.184	1.29	1.42	13.94	3.91	3.98	9.65
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.38	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.203	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	6.80	5.00	37.80	8.60	20.00	14.85
33.60	8.10	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	8.10	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-11

BASIC BLADE DATA
H3 HELICOPTER
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	12.20	2.27	0.100	0.45	0.56	5.13	1.63	1.41	3.59
319.20	13.40	10.99	0.210	0.90	1.12	10.25	3.26	2.83	7.18
302.40	14.60	8.88	0.190	1.15	1.32	12.61	3.69	3.59	8.79
285.60	15.80	8.40	0.180	1.42	1.50	15.21	4.10	4.36	10.55
268.80	17.00	8.27	0.170	1.74	1.71	17.98	4.47	5.32	12.45
252.00	18.20	8.26	0.160	2.12	1.94	23.66	5.41	6.46	14.41
235.20	19.40	8.31	0.150	2.54	2.19	27.42	5.84	7.80	16.56
218.40	20.70	8.40	0.140	3.09	2.49	32.21	6.46	9.28	19.05
201.60	22.00	8.53	0.140	3.69	2.79	37.17	6.99	10.92	21.70
184.80	23.20	8.96	0.140	4.34	3.12	45.41	7.98	12.98	24.23
168.00	24.40	8.97	0.130	4.94	3.38	51.04	8.52	14.69	26.99
151.20	25.60	9.04	0.130	5.68	3.70	57.66	9.22	17.15	29.88
134.40	26.80	9.16	0.130	6.53	4.06	65.18	9.99	19.66	32.89
117.60	28.00	7.85	0.120	7.51	4.47	73.16	10.77	22.25	36.03
100.80	29.20	8.03	0.120	8.71	4.97	82.90	11.68	25.40	39.28
84.00	30.40	8.22	0.120	9.96	5.46	92.90	12.49	29.33	42.66
67.20	14.00	7.44	0.120	11.46	6.04	105.80	13.72	35.34	46.19
50.40	14.50	12.19	0.140	28.51	14.48	138.30	17.37	65.76	49.14
33.60	15.00	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	15.00	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	15.00	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-12

BASIC BLADE DATA
H3 HELICOPTER
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	21.00	2.27	0.064	1.29	1.05	13.29	2.73	3.78	9.54
319.20	20.60	10.99	0.128	2.59	2.10	26.58	5.46	7.57	19.09
302.40	20.10	8.88	0.134	2.50	2.07	25.48	5.40	7.43	18.08
285.60	19.50	8.40	0.140	2.36	2.02	24.11	5.26	7.01	16.90
268.80	18.90	8.27	0.147	2.24	1.97	22.65	5.06	6.76	15.77
252.00	18.40	8.26	0.153	2.17	1.97	24.23	5.48	6.62	14.77
235.20	17.80	8.31	0.164	2.07	1.94	22.72	5.28	6.43	13.66
218.40	17.30	8.40	0.175	2.02	1.95	21.77	5.23	6.19	12.76
201.60	16.70	8.53	0.187	1.91	1.91	20.35	5.06	5.87	11.72
184.80	16.10	8.96	0.201	1.80	1.86	20.36	5.18	5.67	10.66
168.00	15.60	8.97	0.214	1.68	1.80	19.10	5.01	5.32	9.86
151.20	15.10	9.04	0.229	1.58	1.75	18.04	4.92	5.16	9.09
134.40	14.60	9.16	0.244	1.49	1.69	17.04	4.83	4.91	8.32
117.60	14.10	7.85	0.261	1.38	1.64	15.90	4.69	4.59	7.57
100.80	13.60	8.03	0.280	1.28	1.57	14.75	4.51	4.26	6.85
84.00	13.10	8.22	0.302	1.16	1.47	13.57	4.29	4.01	6.13
67.20	5.70	7.44	0.330	1.04	1.38	12.65	4.17	3.93	5.44
50.40	5.40	12.19	0.462	1.46	2.00	12.37	4.28	5.48	4.04
33.60	5.00	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	5.00	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	5.00	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-13

BASIC BLADE DATA
H4 HELICOPTER
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	19.80	3.56	0.073	1.30	1.10	13.25	3.05	3.40	15.90
410.40	19.80	20.70	0.145	2.60	2.20	26.50	6.05	6.80	15.90
388.80	19.80	12.31	0.145	2.60	2.20	26.50	6.05	6.80	15.90
367.20	19.80	12.22	0.150	2.60	2.20	26.50	6.05	6.80	15.90
345.60	19.80	12.13	0.155	2.60	2.20	26.50	6.05	7.00	15.90
324.00	19.80	12.21	0.160	2.72	2.30	26.80	6.15	7.40	15.98
302.40	19.80	11.91	0.165	2.88	2.40	31.20	6.65	7.80	16.10
280.80	19.80	12.10	0.170	2.98	2.45	31.70	6.80	8.20	16.15
259.20	19.80	12.17	0.175	3.00	2.50	32.40	6.95	8.60	16.20
237.60	19.80	12.39	0.180	3.07	2.53	32.90	7.08	9.00	16.24
216.00	19.80	12.83	0.185	3.40	2.80	38.60	7.80	9.40	16.43
194.40	19.80	12.88	0.190	3.57	2.90	39.40	8.00	9.85	16.50
172.80	19.80	11.97	0.195	3.70	3.00	40.25	8.20	10.05	16.56
151.20	19.80	11.61	0.200	3.83	3.10	41.20	8.40	10.70	16.62
129.60	19.80	11.89	0.205	3.99	3.20	42.10	8.60	11.11	16.70
108.00	19.80	12.74	0.210	4.15	3.35	43.10	8.80	11.54	16.75
86.40	8.84	11.26	0.215	4.40	3.50	44.40	9.15	12.62	16.82
64.80	8.84	16.53	0.280	8.50	5.50	54.00	11.20	31.80	17.93
43.20	8.84	74.74	1.000	40.00	14.00	80.00	15.00	50.00	30.00
24.00	8.84	73.92	2.500	80.00	18.00	100.00	20.00	100.00	100.00

DESIGN TWIST -8 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-14

BASIC BLADE DATA
H4 HELICOPTER
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	6.60	3.56	0.163	0.17	0.29	2.47	1.63	0.59	1.52
410.40	9.90	20.70	0.327	0.34	0.57	4.95	2.27	1.19	3.05
388.80	13.20	12.31	0.227	0.93	1.17	10.61	3.61	2.63	6.80
367.20	16.50	12.22	0.183	1.68	1.70	17.77	4.82	4.50	11.59
345.60	19.80	12.13	0.155	2.60	2.20	26.50	6.05	7.00	15.90
324.00	19.80	12.21	0.160	2.72	2.30	26.80	6.15	7.40	15.98
302.40	19.80	11.91	0.165	2.88	2.40	31.20	6.65	7.80	16.10
280.80	19.80	12.10	0.170	2.98	2.45	31.70	6.80	8.20	16.15
259.20	19.80	12.17	0.175	3.00	2.50	32.40	6.95	8.60	16.20
237.60	19.80	12.39	0.180	3.07	2.53	32.90	7.08	9.00	16.24
216.00	19.80	12.83	0.185	3.40	2.80	38.60	7.80	9.40	16.43
194.40	19.80	12.88	0.190	3.57	2.90	39.40	8.00	9.85	16.50
172.80	19.80	11.97	0.195	3.70	3.00	40.25	8.20	10.05	16.56
151.20	19.80	11.61	0.200	3.83	3.10	41.20	8.40	10.70	16.62
129.60	19.80	11.89	0.205	3.99	3.20	42.10	8.60	11.11	16.70
108.00	19.80	12.74	0.210	4.15	3.35	43.10	8.80	11.54	16.75
86.40	8.84	11.26	0.215	4.40	3.50	44.40	9.15	12.62	16.82
64.80	8.84	16.53	0.280	8.50	5.50	54.00	11.20	31.80	17.93
43.20	8.84	74.74	1.000	40.00	14.00	80.00	15.00	50.00	30.00
24.00	8.84	73.92	2.500	80.00	18.00	100.00	20.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-15

BASIC BLADE DATA
H4 HELICOPTER
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX (IN.4)	SEC-TION ZXX (IN.3)	EDGE-WISE IYY (IN.4)	SEC-TION ZYY (IN.3)	TOR-SION J (IN.4)	MID-LINE AREA (IN.2)
432.00	13.40	3.56	0.102	0.60	0.69	6.61	2.04	1.65	4.27
410.40	14.50	20.70	0.204	1.20	1.38	13.23	4.09	3.31	8.54
388.80	15.90	12.31	0.184	1.53	1.60	16.36	4.60	4.13	10.64
367.20	17.30	12.22	0.174	1.87	1.81	19.62	5.09	4.99	12.83
345.60	18.50	12.13	0.167	2.22	2.00	22.87	5.53	5.84	15.01
324.00	19.80	12.21	0.160	2.72	2.29	26.80	5.97	7.13	17.39
302.40	21.20	11.91	0.153	3.38	2.66	36.16	7.31	8.81	20.06
280.80	22.40	12.10	0.149	3.97	2.95	41.36	7.85	10.45	22.57
259.20	23.75	12.17	0.144	4.57	3.21	47.91	8.57	12.53	25.56
237.60	25.10	12.39	0.140	5.30	3.52	54.73	9.23	14.85	28.74
216.00	26.45	12.83	0.136	6.64	4.19	71.96	11.37	17.45	31.98
194.40	27.80	12.88	0.133	7.82	4.69	81.70	12.25	20.38	35.48
172.80	29.20	11.97	0.129	9.06	5.17	92.68	13.17	23.68	39.32
151.20	30.40	11.61	0.127	10.27	5.63	103.30	14.11	27.00	42.76
129.60	31.70	11.89	0.124	11.78	6.19	115.50	15.08	30.74	46.62
108.00	33.00	12.74	0.122	13.41	6.77	128.80	16.18	34.86	50.68
86.40	15.50	11.26	0.120	15.65	7.58	145.10	17.53	39.62	55.20
64.80	16.00	16.53	0.147	36.25	16.93	199.70	22.36	52.29	58.38
43.20	16.50	74.74	1.000	40.00	14.00	80.00	15.00	50.00	30.00
24.00	16.50	73.92	2.500	80.00	18.00	100.00	20.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-16

BASIC BLADE DATA
H4 HELICOPTER
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	22.66	3.56	0.065	1.65	1.25	16.60	3.36	4.28	10.95
410.40	22.00	20.70	0.130	3.31	2.51	33.20	6.72	8.57	21.91
388.80	21.48	12.31	0.133	3.13	2.43	31.55	6.54	8.13	20.83
367.20	20.75	12.22	0.143	2.90	2.33	29.30	6.30	7.54	19.33
345.60	20.25	12.13	0.151	2.74	2.25	27.81	6.14	7.15	18.32
324.00	19.60	12.21	0.162	2.66	2.26	26.22	5.90	6.97	17.01
302.40	19.10	11.91	0.172	2.64	2.31	28.85	6.48	6.98	15.93
280.80	18.60	12.10	0.182	2.56	2.30	27.64	6.34	6.90	14.96
259.20	18.10	12.17	0.193	2.41	2.22	26.59	6.26	6.83	14.01
237.60	17.50	12.39	0.206	2.27	2.16	25.02	6.08	6.63	12.92
216.00	16.80	12.83	0.222	2.24	2.23	26.67	6.67	6.26	11.58
194.40	16.40	12.88	0.234	2.20	2.24	25.69	6.57	6.17	10.86
172.80	15.70	11.97	0.253	2.01	2.14	23.63	6.30	5.77	9.70
151.20	15.25	11.61	0.269	1.91	2.08	22.51	6.18	5.58	8.96
129.60	14.70	11.89	0.288	1.76	2.00	20.92	5.95	5.25	8.07
108.00	14.10	12.74	0.311	1.59	1.88	19.21	5.72	4.86	7.18
86.40	6.30	11.26	0.337	1.43	1.77	17.53	5.48	4.44	6.28
64.80	6.00	16.53	0.497	1.47	1.90	15.84	5.04	3.89	4.23
43.20	5.80	74.74	1.000	40.00	14.00	80.00	15.00	50.00	30.00
24.00	5.80	73.92	2.500	80.00	18.00	100.00	20.00	100.00	100.00

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-17

BASIC BLADE DATA
H1-R HELICOPTER
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	18.25	2.56	0.072	0.97	0.90	10.10	2.50	2.80	6.46
353.40	18.25	12.57	0.145	1.93	1.80	20.30	5.00	5.50	12.92
334.80	18.25	9.51	0.145	1.95	1.82	20.50	5.00	5.70	12.94
316.20	18.25	9.19	0.146	1.99	1.84	20.60	5.03	5.90	12.96
297.60	18.25	9.18	0.149	2.00	1.90	20.80	5.10	6.00	12.98
279.00	18.25	9.29	0.151	2.04	1.90	20.90	5.12	6.30	13.00
260.40	18.25	9.03	0.154	2.10	1.95	23.70	5.50	6.60	13.10
241.80	18.25	9.14	0.158	2.19	2.00	24.00	5.60	6.80	13.13
223.20	18.25	9.45	0.163	2.29	2.10	24.30	5.50	7.00	13.20
204.60	18.25	9.37	0.169	2.35	2.20	24.80	5.80	7.30	13.25
186.00	18.25	9.91	0.175	2.45	2.25	27.00	6.13	7.60	13.35
167.40	18.25	9.94	0.180	2.51	2.30	27.30	6.20	7.90	13.38
148.80	18.25	10.01	0.186	2.60	2.36	28.00	6.27	8.20	13.40
130.20	18.25	9.73	0.191	2.71	2.40	28.50	6.40	8.50	13.47
111.60	18.25	8.78	0.196	2.80	2.50	29.30	6.58	9.00	13.52
93.00	18.25	9.06	0.202	2.91	2.60	29.80	6.70	9.90	13.58
74.40	8.10	8.53	0.210	3.04	2.70	30.50	6.92	14.00	13.68
55.80	8.10	10.51	0.265	4.40	3.60	35.00	7.95	30.00	14.10
37.20	8.10	55.21	1.000	5.00	5.00	26.00	6.00	50.00	50.00
18.60	8.10	84.17	2.000	5.00	5.00	26.00	6.00	100.00	100.00
12.63	8.10	20.46	2.000	5.00	5.00	26.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.2 DEG. AT -2 DEG DESIGN TWIST PRELAG ANGLE -12.2 DEG

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-18

BASIC BLADE DATA
H1-R HELICOPTER
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	6.08	2.56	0.164	0.12	0.22	1.86	2.50	0.48	1.26
353.40	9.12	12.57	0.329	0.24	0.44	3.72	5.00	0.96	2.52
334.80	12.16	9.51	0.228	0.68	0.94	8.13	5.00	2.20	5.65
316.20	15.20	9.19	0.178	1.28	1.40	13.76	3.86	3.90	9.68
297.60	18.25	9.18	0.149	2.00	1.90	20.80	5.10	6.00	12.98
279.00	18.25	9.29	0.151	2.04	1.90	20.90	5.12	6.30	13.00
260.40	18.25	9.03	0.154	2.10	1.95	23.70	5.50	6.60	13.10
241.80	18.25	9.14	0.158	2.19	2.00	24.00	5.60	6.80	13.13
223.20	18.25	9.45	0.163	2.29	2.10	24.30	5.50	7.00	13.20
204.60	18.25	9.37	0.169	2.35	2.20	24.80	5.80	7.30	13.25
186.00	18.25	9.91	0.175	2.45	2.25	27.00	6.13	7.60	13.35
167.40	18.25	9.94	0.180	2.51	2.30	27.30	6.20	7.90	13.38
148.80	18.25	10.01	0.186	2.60	2.36	28.00	6.27	8.20	13.40
130.20	18.25	9.73	0.191	2.71	2.40	28.50	6.40	8.50	13.47
111.60	18.25	8.78	0.196	2.80	2.50	29.30	6.58	9.00	13.52
93.00	18.25	9.06	0.202	2.91	2.60	29.80	6.70	9.90	13.58
74.40	8.10	8.53	0.210	3.04	2.70	30.50	6.92	14.00	13.68
55.80	8.10	10.51	0.265	4.40	3.60	35.00	7.95	30.00	14.10
37.20	8.10	55.21	1.000	5.00	5.00	26.00	6.00	50.00	50.00
18.60	8.10	84.17	2.000	5.00	5.00	26.00	6.00	100.00	100.00
12.63	8.10	20.46	2.000	5.00	5.00	26.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.18 DEG. AT -4 DEG TWIST PRELAG ANGLE -11.7 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-19

BASIC BLADE DATA
H1-R HELICOPTER
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
372.00	12.20	2.56	0.100	0.45	0.56	5.17	1.64	1.40	3.67
353.40	13.50	12.57	0.200	0.91	1.12	10.34	3.29	2.78	7.34
334.80	14.70	9.51	0.180	1.16	1.31	12.80	3.71	3.50	9.04
316.20	16.00	9.19	0.170	1.45	1.51	15.43	4.11	4.38	10.89
297.60	17.20	9.18	0.160	1.74	1.68	18.28	4.53	5.25	12.81
279.00	18.40	9.29	0.150	2.11	1.89	21.53	4.93	6.29	15.05
260.40	19.50	9.03	0.140	2.45	2.10	27.36	5.82	7.54	16.83
241.80	20.80	9.14	0.140	2.94	2.37	31.52	6.29	9.00	19.11
223.20	22.00	9.45	0.130	3.54	2.68	36.37	6.81	10.45	21.77
204.60	23.20	9.37	0.130	4.10	2.95	41.61	7.42	12.26	24.34
186.00	24.40	9.91	0.130	4.82	3.29	50.53	8.44	14.29	27.02
167.40	25.60	9.94	0.130	5.54	3.60	57.04	9.05	16.63	30.16
148.80	26.80	10.01	0.120	6.27	3.91	63.47	9.78	18.78	32.67
130.20	28.00	9.73	0.120	7.43	4.42	73.13	10.70	22.09	36.03
111.60	29.20	8.78	0.120	8.58	4.89	83.53	11.81	25.46	39.28
93.00	30.40	9.06	0.120	9.94	5.43	94.14	12.68	30.23	42.95
74.40	14.10	8.53	0.120	11.59	6.07	106.90	13.79	34.33	46.79
55.80	14.70	10.51	0.140	17.75	8.99	126.62	15.88	51.35	49.92
37.20	14.70	55.21	1.000	25.00	14.00	18.00	10.00	50.00	50.00
18.60	14.70	84.17	2.000	30.00	18.00	18.00	15.00	100.00	100.00
12.63	14.70	20.46	2.000	30.00	18.00	18.00	15.00	100.00	100.00

BEARING FLEXIBILITY 10 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.45 DEG. AT -4 DEG TWIST PRELAG ANGLE -13.0 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-20

BASIC BLADE DATA
H1-R HELICOPTER
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX $(IN.^4)$	SEC-TION ZXX $(IN.^3)$	EDGE-WISE IYY $(IN.^4)$	SEC-TION ZYY $(IN.^3)$	TOR-SION J $(IN.^4)$	MID-LINE AREA $(IN.^2)$
372.00	21.00	2.56	0.065	1.25	1.02	12.90	2.70	3.58	9.36
353.40	20.40	12.57	0.129	2.50	2.04	25.80	5.40	7.16	18.72
334.80	19.80	9.51	0.133	2.35	1.98	24.43	5.25	6.83	17.53
316.20	19.30	9.19	0.138	2.27	1.96	23.24	5.12	6.68	16.56
297.60	18.80	9.18	0.144	2.14	1.90	22.18	5.02	6.41	15.61
279.00	18.40	9.29	0.150	2.08	1.88	21.27	4.90	6.21	14.87
260.40	17.80	9.03	0.158	1.98	1.85	22.44	5.23	6.14	13.74
241.80	17.30	9.14	0.167	1.92	1.85	21.34	5.11	6.02	12.83
223.20	16.70	9.45	0.180	1.84	1.84	19.96	4.94	5.63	11.79
204.60	16.20	9.37	0.192	1.75	1.80	19.01	4.87	5.46	10.93
186.00	15.70	9.91	0.207	1.67	1.77	19.22	5.02	5.27	10.05
167.40	15.20	9.94	0.221	1.57	1.72	18.01	4.86	5.06	9.27
148.80	14.60	10.01	0.239	1.45	1.65	16.77	4.76	4.75	8.36
130.20	14.10	9.73	0.256	1.36	1.60	15.66	4.59	4.50	7.61
111.60	13.60	8.78	0.275	1.25	1.53	14.68	4.50	4.23	6.88
93.00	13.00	9.06	0.300	1.11	1.42	13.24	4.23	3.98	6.03
74.40	5.50	8.53	0.328	1.00	1.33	12.15	4.04	3.63	5.35
55.80	5.50	10.51	0.447	1.06	1.47	11.67	4.12	4.83	4.27
37.20	5.00	55.21	1.000	5.00	14.00	80.00	10.00	50.00	50.00
18.60	5.00	84.17	2.000	10.00	18.00	80.00	15.00	100.00	100.00
12.63	5.00	20.46	2.000	10.00	18.00	80.00	15.00	100.00	100.00

BEARING FLEXIBILITY 10 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.00 DEG. AT -4 DEG TWIST PRELAG ANGLE -12.2 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-21

BASIC BLADE DATA
H2-R HELICOPTER
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	23.65	6.97	0.081	1.87	1.38	19.90	3.80	5.90	9.55
410.40	23.65	19.60	0.162	3.75	2.92	39.80	7.80	12.70	19.20
388.80	23.65	14.51	0.183	4.20	3.24	42.90	8.50	15.00	19.40
367.20	23.65	15.77	0.204	4.75	3.62	53.00	9.80	14.90	19.73
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	10.00	6.00	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	10.00	7.00	43.00	10.00	100.00	100.00
43.20	9.71	77.12	3.000	10.00	7.00	43.00	10.00	150.00	100.00
24.00	9.71	84.59	3.000	10.00	7.00	43.00	10.00	150.00	100.00

BEARING FLEXIBILITY 20 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.3 DEG. AT 0 DEG DESIGN TWIST PRELAG ANGLE -6.7 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-22

BASIC BLADE DATA
H2-R HELICOPTER
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	7.88	6.97	0.180	0.27	0.39	3.83	1.59	1.10	2.13
410.40	11.82	19.60	0.361	0.55	0.78	7.66	3.19	2.20	4.27
388.80	15.76	14.51	0.287	1.51	1.60	17.13	5.30	5.34	8.98
367.20	19.70	15.77	0.249	3.03	2.56	35.24	8.24	10.60	14.90
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	10.00	6.00	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	10.00	7.00	43.00	10.00	100.00	100.00
43.20	9.71	77.12	3.000	10.00	7.00	43.00	10.00	150.00	100.00
24.00	9.71	84.59	3.000	10.00	7.00	43.00	10.00	150.00	100.00

BEARING FLEXIBILITY 20 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.3 DEG. AT -8 DEG TWIST PRELAG ANGLE -5.47 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-23

BASIC BLADE DATA
H2-R HELICOPTER
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	15.80	6.97	0.113	0.89	0.86	10.11	2.82	2.95	5.80
410.40	17.40	19.60	0.226	1.79	1.72	20.22	5.64	5.90	11.61
388.80	18.90	14.51	0.232	2.48	2.18	26.48	6.77	8.36	14.06
367.20	20.50	15.77	0.239	3.35	2.73	38.58	8.66	11.63	16.35
345.60	22.00	15.74	0.229	4.24	3.21	47.11	9.92	14.43	19.10
324.00	23.70	17.14	0.216	5.45	3.83	65.10	12.45	19.09	22.37
302.40	25.30	10.29	0.204	6.62	4.35	76.43	13.63	22.44	26.07
280.80	26.80	17.63	0.196	7.66	4.76	86.88	14.70	25.83	29.29
259.20	28.50	17.02	0.194	8.30	5.03	92.99	15.35	27.91	31.00
237.60	30.00	18.04	0.180	10.40	5.78	113.00	17.07	34.13	37.43
216.00	31.60	17.71	0.173	11.90	6.28	127.60	18.35	39.16	41.84
194.40	33.20	16.61	0.167	13.65	6.84	143.90	19.67	44.39	46.60
172.80	34.70	16.42	0.164	14.84	7.20	155.30	20.58	48.29	49.93
151.20	36.40	16.42	0.157	17.31	7.93	177.70	22.23	56.03	56.39
129.60	37.90	17.33	0.155	19.25	8.44	200.20	23.82	62.41	61.65
108.00	16.20	18.46	0.167	26.92	11.36	246.50	28.26	77.42	66.44
86.40	16.90	38.11	0.193	35.00	15.00	486.30	54.83	294.40	72.42
64.80	16.90	124.62	3.000	50.00	13.00	34.00	10.00	100.00	100.00
43.20	16.90	77.12	3.000	50.00	13.00	34.00	10.00	150.00	100.00
24.00	16.90	84.59	3.000	50.00	13.00	34.00	10.00	150.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.4 DEG. AT -8 DEG TWIST PRELAG ANGLE -5.9 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-24

BASIC BLADE DATA
H2-R HELICOPTER
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 33,000 LB., 150-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	27.00	6.97	0.072	2.40	1.51	25.15	4.59	7.48	14.68
410.40	26.40	19.60	0.144	4.80	3.03	50.29	9.19	14.97	29.36
388.80	25.70	14.51	0.168	5.08	3.29	51.26	9.65	16.43	27.54
367.20	25.00	15.77	0.192	5.41	3.61	59.81	10.98	18.21	25.57
345.60	24.40	15.74	0.205	5.44	3.71	59.22	11.22	18.23	24.11
324.00	23.60	17.14	0.217	5.39	3.81	64.50	12.38	18.91	22.16
302.40	22.90	10.29	0.228	5.16	3.75	60.77	12.04	17.74	20.63
280.80	22.30	17.63	0.239	4.91	3.67	57.84	11.79	17.03	19.34
259.20	21.60	17.02	0.252	4.62	3.57	54.45	11.48	16.13	17.95
237.60	21.00	18.04	0.265	4.40	3.50	51.39	11.15	15.24	16.76
216.00	20.30	17.71	0.281	4.09	3.36	47.98	10.81	14.40	15.43
194.40	19.60	16.61	0.297	3.79	3.22	44.63	10.42	13.40	14.11
172.80	18.90	16.42	0.316	3.46	3.05	41.18	10.00	12.42	12.88
151.20	18.20	16.42	0.336	3.16	2.89	37.89	9.58	11.54	11.64
129.60	17.50	17.33	0.365	2.80	2.66	35.11	9.18	10.53	10.42
108.00	7.00	18.46	0.434	2.97	2.93	35.09	9.55	10.59	90.37
86.40	6.70	38.11	0.710	3.50	3.60	28.04	8.69	23.93	44.19
64.80	6.70	124.62	3.000	10.00	7.00	60.00	10.00	100.00	100.00
43.20	6.70	77.12	3.000	10.00	7.00	60.00	10.00	150.00	100.00
24.00	6.70	84.59	3.000	10.00	7.00	60.00	10.00	150.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.1 DEG. AT -8 DEG TWIST PRELAG ANGLE -5.95 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-25

BASIC BLADE DATA
H3-R HELICOPTER
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	18.25	2.27	0.072	0.98	0.92	10.30	2.50	2.90	12.94
319.20	18.25	10.99	0.146	1.96	1.84	20.50	5.00	5.90	12.94
302.40	18.25	8.88	0.148	2.00	1.88	20.70	5.10	6.02	12.98
285.60	18.25	8.40	0.151	2.02	1.90	20.90	5.10	6.15	13.00
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.31	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.213	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	5.00	3.00	23.00	6.00	20.00	14.85
33.60	8.10	69.17	1.500	5.00	3.00	23.00	6.00	35.00	50.00
16.80	8.10	71.84	2.000	5.00	3.00	23.00	6.00	100.00	100.00
12.63	8.10	14.80	2.000	5.00	3.00	23.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.45 DEG. AT 0 DEG DESIGN TWIST PRELAG ANGLE -10.7 DEG

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-26

BASIC BLADE DATA
H3-R HELICOPTER
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	6.08	2.27	0.161	0.12	0.22	1.87	0.89	0.49	1.25
319.20	9.12	10.99	0.332	0.24	0.44	3.73	1.77	0.99	2.50
302.40	12.16	8.88	0.233	0.69	0.95	8.19	2.89	2.29	5.62
285.60	15.20	8.40	0.184	1.29	1.42	13.94	3.91	3.98	9.65
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.38	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.203	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	5.00	3.00	23.00	6.00	20.00	14.85
33.60	8.10	69.17	1.500	5.00	3.00	23.00	6.00	35.00	50.00
16.80	8.10	71.84	2.000	5.00	3.00	23.00	6.00	100.00	100.00
12.63	8.10	14.80	2.000	5.00	3.00	23.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.4 DEG. AT -4 DEG TWIST PRELAG ANGLE -9.14 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-27

BASIC BLADE DATA
H3-R HELICOPTER
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	12.20	2.27	0.100	0.45	0.56	5.13	1.63	1.41	3.59
319.20	13.40	10.99	0.210	0.90	1.12	10.25	3.26	2.83	7.18
302.40	14.60	8.88	0.190	1.15	1.32	12.61	3.69	3.59	8.79
285.60	15.80	8.40	0.180	1.42	1.50	15.21	4.10	4.36	10.55
268.80	17.00	8.27	0.170	1.74	1.71	17.98	4.47	5.32	12.45
252.00	18.20	8.26	0.160	2.12	1.94	23.66	5.41	6.46	14.41
235.20	19.40	8.31	0.150	2.54	2.19	27.42	5.84	7.80	16.56
218.40	20.70	8.40	0.140	3.09	2.49	32.21	6.46	9.28	19.05
201.60	22.00	8.53	0.140	3.69	2.79	37.17	6.99	10.92	21.70
184.80	23.20	8.96	0.140	4.34	3.12	45.41	7.98	12.98	24.23
168.00	24.40	8.97	0.130	4.94	3.38	51.04	8.52	14.69	26.99
151.20	25.60	9.04	0.130	5.68	3.70	57.66	9.22	17.15	29.88
134.40	26.80	9.16	0.130	6.53	4.06	65.18	9.99	19.66	32.89
117.60	28.00	7.85	0.120	7.51	4.47	73.16	10.77	22.25	36.03
100.80	29.20	8.03	0.120	8.71	4.97	82.90	11.68	25.40	39.28
84.00	30.40	8.22	0.120	9.96	5.46	92.90	12.49	29.33	42.66
67.20	14.00	7.44	0.120	11.46	6.04	105.80	13.72	35.34	46.19
50.40	14.50	12.19	0.140	28.51	14.48	18.00	10.00	65.76	49.14
33.60	15.00	69.17	1.500	30.00	15.00	18.00	10.00	35.00	50.00
16.80	15.00	71.84	2.000	30.00	15.00	18.00	10.00	100.00	100.00
12.63	15.00	14.80	2.000	30.00	15.00	18.00	10.00	100.00	100.00

BEARING FLEXIBILITY 10 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.75 DEG. AT -4 DEG TWIST PRELAG ANGLE -11.12 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-28

BASIC BLADE DATA
H3-R HELICOPTER
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 8,700 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	21.00	2.27	0.064	1.29	1.05	13.29	2.73	3.78	9.54
319.20	20.60	10.99	0.128	2.59	2.10	26.58	5.46	7.57	19.09
302.40	20.10	8.86	0.134	2.50	2.07	25.48	5.40	7.43	18.08
285.60	19.50	8.40	0.140	2.36	2.02	24.11	5.26	7.01	16.90
268.80	18.90	8.27	0.147	2.24	1.97	22.65	5.06	6.76	15.77
252.00	18.40	8.26	0.153	2.17	1.97	24.23	5.48	6.62	14.77
235.20	17.80	8.31	0.164	2.07	1.94	22.72	5.28	6.43	13.66
218.40	17.30	8.40	0.175	2.02	1.95	21.77	5.23	6.19	12.76
201.60	16.70	8.53	0.187	1.91	1.91	20.35	5.06	5.87	11.72
184.80	16.10	8.96	0.201	1.80	1.86	20.36	5.18	5.67	10.66
168.00	15.60	8.97	0.214	1.68	1.80	19.10	5.01	5.32	9.86
151.20	15.10	9.04	0.229	1.58	1.75	18.04	4.92	5.16	9.09
134.40	14.60	9.16	0.244	1.49	1.69	17.04	4.83	4.91	8.32
117.60	14.10	7.85	0.261	1.38	1.64	15.90	4.69	4.59	7.57
100.80	13.60	8.03	0.280	1.28	1.57	14.75	4.51	4.26	6.85
84.00	13.10	8.22	0.302	1.16	1.47	13.57	4.29	4.01	6.13
67.20	5.70	7.44	0.330	1.04	1.38	12.65	4.17	3.93	5.44
50.40	5.40	12.19	0.462	1.46	2.00	40.00	10.00	5.48	4.04
33.60	5.00	69.17	1.500	8.00	5.00	40.00	10.00	35.00	50.00
16.80	5.00	71.84	2.000	8.00	5.00	40.00	10.00	100.00	100.00
12.63	5.00	14.80	2.000	8.00	5.00	40.00	10.00	100.00	100.00

BEARING FLEXIBILITY 10 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.3 DEG. AT -4 DEG TWIST PRELAG ANGLE -10.12 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-29

BASIC BLADE DATA
H4-R HELICOPTER
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	19.80	3.56	0.073	1.30	1.10	13.25	3.05	3.40	15.90
410.40	19.80	20.70	0.145	2.60	2.20	26.50	6.05	6.80	15.90
388.80	19.80	12.31	0.145	2.60	2.20	26.50	6.05	6.80	15.90
367.20	19.80	12.22	0.150	2.60	2.20	26.50	6.05	6.80	15.90
345.60	19.80	12.13	0.155	2.60	2.20	26.50	6.05	7.00	15.90
324.00	19.80	12.21	0.160	2.72	2.30	26.80	6.15	7.40	15.98
302.40	19.80	11.91	0.165	2.88	2.40	31.20	6.65	7.80	16.10
280.80	19.80	12.10	0.170	2.98	2.45	31.70	6.80	8.20	16.15
259.20	19.80	12.17	0.175	3.00	2.50	32.40	6.95	8.60	16.20
237.60	19.80	12.39	0.180	3.07	2.53	32.90	7.08	9.00	16.24
216.00	19.80	12.83	0.185	3.40	2.80	38.60	7.80	9.40	16.43
194.40	19.80	12.88	0.190	3.57	2.90	39.40	8.00	9.85	16.50
172.80	19.80	11.97	0.195	3.70	3.00	40.25	8.20	10.05	16.56
151.20	19.80	11.61	0.200	3.83	3.10	41.20	8.40	10.70	16.62
129.60	19.80	11.89	0.205	3.99	3.20	42.10	8.60	11.11	16.70
108.00	19.80	12.74	0.210	4.15	3.35	43.10	8.80	11.54	16.75
86.40	8.84	11.26	0.215	4.40	3.50	44.40	9.15	12.62	16.82
64.80	8.84	16.53	0.280	30.00	10.00	35.00	7.00	31.80	17.93
43.20	8.84	74.74	1.000	50.00	15.00	35.00	7.00	50.00	30.00
24.00	8.84	73.92	2.500	50.00	15.00	35.00	7.00	100.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.35 DEG. AT -4 DEG DESIGN TWIST PRELAG ANGLE -10.1 DE

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-30

BASIC BLADE DATA
H4-R HELICOPTER
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	6.60	3.56	0.163	0.17	0.29	2.47	1.63	0.59	1.52
410.40	9.90	20.70	0.327	0.34	0.57	4.95	2.27	1.19	3.05
388.80	13.20	12.31	0.227	0.93	1.17	10.61	3.61	2.63	6.80
367.20	16.50	12.22	0.183	1.68	1.70	17.77	4.82	4.50	11.59
345.60	19.80	12.13	0.155	2.60	2.20	26.50	6.05	7.00	15.90
324.00	19.80	12.21	0.160	2.72	2.30	26.80	6.15	7.40	15.98
302.40	19.80	11.91	0.165	2.88	2.40	31.20	6.65	7.80	16.10
280.80	19.80	12.10	0.170	2.98	2.45	31.70	6.80	8.20	16.15
259.20	19.80	12.17	0.175	3.00	2.50	32.40	6.95	8.60	16.20
237.60	19.80	12.39	0.180	3.07	2.53	32.90	7.08	9.00	16.24
216.00	19.80	12.83	0.185	3.40	2.80	38.60	7.80	9.40	16.43
194.40	19.80	12.88	0.190	3.57	2.90	39.40	8.00	9.85	16.50
172.80	19.80	11.97	0.195	3.70	3.00	40.25	8.20	10.05	16.56
151.20	19.80	11.61	0.200	3.83	3.10	41.20	8.40	10.70	16.62
129.60	19.80	11.89	0.205	3.99	3.20	42.10	8.60	11.11	16.70
108.00	19.80	12.74	0.210	4.15	3.35	43.10	8.80	11.54	16.75
86.40	8.84	11.26	0.215	4.40	3.50	44.40	9.15	12.62	16.82
64.80	8.84	16.53	0.280	30.00	10.00	35.00	7.00	31.80	17.93
43.20	8.84	74.74	1.000	50.00	15.00	35.00	7.00	50.00	30.00
24.00	8.84	73.92	2.500	50.00	15.00	35.00	7.00	100.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.6 DEG. AT -4 DEG TWIST PRELAG ANGLE -6.99 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-31

BASIC BLADE DATA
H4-R HELICOPTER
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	13.40	3.56	0.102	0.60	0.69	6.61	2.04	1.65	4.27
410.40	14.50	20.70	0.204	1.20	1.38	13.23	4.09	3.31	8.54
388.80	15.90	12.31	0.184	1.53	1.60	16.36	4.60	4.13	10.64
367.20	17.30	12.22	0.174	1.87	1.81	19.62	5.09	4.99	12.83
345.60	18.50	12.13	0.167	2.22	2.00	22.87	5.53	5.84	15.01
324.00	19.80	12.21	0.160	2.72	2.29	26.80	5.97	7.13	17.39
302.40	21.20	11.91	0.153	3.38	2.66	36.16	7.31	8.81	20.06
280.80	22.40	12.10	0.149	3.97	2.95	41.36	7.85	10.45	22.57
259.20	23.75	12.17	0.144	4.57	3.21	47.91	8.57	12.53	25.56
237.60	25.10	12.39	0.140	5.30	3.52	54.73	9.23	14.85	28.74
216.00	26.45	12.83	0.136	6.64	4.19	71.96	11.37	17.45	31.98
194.40	27.80	12.88	0.133	7.82	4.69	81.70	12.25	20.38	35.48
172.80	29.20	11.97	0.129	9.06	5.17	92.68	13.17	23.68	39.32
151.20	30.40	11.61	0.127	10.27	5.63	103.30	14.11	27.00	42.76
129.60	31.70	11.89	0.124	11.78	6.19	115.50	15.08	30.74	46.62
108.00	93.00	12.74	0.122	13.41	6.77	128.80	16.18	34.86	50.68
86.40	15.50	11.26	0.120	15.65	7.58	145.10	17.53	39.62	55.20
64.80	16.00	16.53	0.147	30.00	15.00	26.00	10.00	52.29	58.38
43.20	16.50	74.74	1.000	50.00	20.00	26.00	10.00	50.00	30.00
24.00	16.50	73.92	2.500	50.00	20.00	26.00	10.00	100.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.6 DEG. AT -4 DEG TWIST PRELAG ANGLE -11.11 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-32

BASIC BLADE DATA
H4-R HELICOPTER
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 180-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICKNESS (IN.)	FLATWISE IXX ($IN.^4$)	SECTION ZXX ($IN.^3$)	EDGEWISE IYY ($IN.^4$)	SECTION ZYY ($IN.^3$)	TORSION J ($IN.^4$)	MIDLINE AREA ($IN.^2$)
432.00	22.66	3.56	0.065	1.65	1.25	16.60	3.36	4.28	10.95
410.40	22.00	20.70	0.130	3.31	2.51	33.20	6.72	8.57	21.91
388.80	21.48	12.31	0.133	3.13	2.43	31.55	6.54	8.13	20.83
367.20	20.75	12.22	0.143	2.90	2.33	29.30	6.30	7.54	19.33
345.60	20.25	12.13	0.151	2.74	2.25	27.81	6.14	7.15	18.32
324.00	19.60	12.21	0.162	2.66	2.26	26.22	5.90	6.97	17.01
302.40	19.10	11.91	0.172	2.64	2.31	28.85	6.48	6.98	15.93
280.80	18.60	12.10	0.182	2.56	2.30	27.64	6.34	6.90	14.96
259.20	18.10	12.17	0.193	2.41	2.22	26.59	6.26	6.83	14.01
237.60	17.50	12.39	0.206	2.27	2.16	25.02	6.08	6.63	12.92
216.00	16.80	12.83	0.222	2.24	2.23	26.67	6.67	6.26	11.58
194.40	16.40	12.88	0.234	2.20	2.24	25.69	6.57	6.17	10.86
172.80	15.70	11.97	0.253	2.01	2.14	23.63	6.30	5.77	9.70
151.20	15.25	11.61	0.269	1.91	2.08	22.51	6.18	5.58	8.96
129.60	14.70	11.89	0.288	1.76	2.00	20.92	5.95	5.25	8.07
108.00	14.10	12.74	0.311	1.59	1.88	19.21	5.72	4.86	7.18
86.40	6.30	11.26	0.337	1.43	1.77	17.53	5.48	4.44	6.28
64.80	6.00	16.53	0.497	8.00	6.00	50.00	10.00	3.89	4.23
43.20	5.80	74.74	1.000	8.00	6.00	50.00	10.00	50.00	30.00
24.00	5.80	73.92	2.500	8.00	6.00	50.00	10.00	100.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 4.15 DEG. AT -4 DEG TWIST PRELAG ANGLE -9.95 DEG.

TWIST VARIATIONS 0, -4, -8, -16 DEG.

TABLE B-33

BASIC BLADE DATA
C1 COMPOUND
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	18.25	2.27	0.072	0.98	0.92	10.30	2.50	2.90	12.94
319.20	18.25	10.99	0.146	1.96	1.84	20.50	5.00	5.90	12.94
302.40	18.25	8.88	0.148	2.00	1.88	20.70	5.10	6.02	12.98
285.60	18.25	8.40	0.151	2.02	1.90	20.90	5.10	6.15	13.00
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.31	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.213	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	6.80	5.00	37.80	8.60	20.00	14.85
33.60	8.10	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	8.10	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

DESIGN TWIST -4 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-34

BASIC BLADE DATA
C1 COMPOUND
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	6.08	2.27	0.161	0.12	0.22	1.87	0.89	0.49	1.25
319.20	9.12	10.99	0.332	0.24	0.44	3.73	1.77	0.99	2.50
302.40	12.16	8.88	0.233	0.69	0.95	8.19	2.89	2.29	5.62
285.60	15.20	8.40	0.184	1.29	1.42	13.94	3.91	3.98	9.65
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.38	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.203	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	6.80	5.00	37.80	8.60	20.00	14.85
33.60	8.10	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	8.10	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-35

BASIC BLADE DATA
C1 COMPOUND
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	12.20	2.27	0.100	0.45	0.56	5.13	1.63	1.41	3.59
319.20	13.40	10.99	0.210	0.90	1.12	10.25	3.26	2.83	7.18
302.40	14.60	8.88	0.190	1.15	1.32	12.61	3.69	3.59	8.79
285.60	15.80	8.40	0.180	1.42	1.50	15.21	4.10	4.36	10.55
268.80	17.00	8.27	0.170	1.74	1.71	17.98	4.47	5.32	12.45
252.00	18.20	8.26	0.160	2.12	1.94	23.66	5.41	6.46	14.41
235.20	19.40	8.31	0.150	2.54	2.19	27.42	5.84	7.80	16.56
218.40	20.70	8.40	0.140	3.09	2.49	32.21	6.46	9.28	19.05
201.60	22.00	8.53	0.140	3.69	2.79	37.17	6.99	10.92	21.70
184.80	23.20	8.96	0.140	4.34	3.12	45.41	7.98	12.98	24.23
168.00	24.40	8.97	0.130	4.94	3.38	51.04	8.52	14.69	26.99
151.20	25.60	9.04	0.130	5.68	3.70	57.66	9.22	17.15	29.88
134.40	26.80	9.16	0.130	6.53	4.06	65.18	9.99	19.66	32.89
117.60	28.00	7.85	0.120	7.51	4.47	73.16	10.77	22.25	36.03
100.80	29.20	8.03	0.120	8.71	4.97	82.90	11.68	25.40	39.28
84.00	30.40	8.22	0.120	9.96	5.46	92.90	12.49	29.33	42.66
67.20	14.00	7.44	0.120	11.46	6.04	105.80	13.72	35.34	46.19
50.40	14.50	12.19	0.140	28.51	14.48	138.30	17.37	65.76	49.14
33.60	15.00	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	15.00	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	15.00	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-36

BASIC BLADE DATA
C1 COMPOUND
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	21.00	2.27	0.064	1.29	1.05	13.29	2.73	3.78	9.54
319.20	20.60	10.99	0.128	2.59	2.10	26.58	5.46	7.57	19.09
302.40	20.10	8.88	0.134	2.50	2.07	25.48	5.40	7.43	18.08
285.60	19.50	8.40	0.140	2.36	2.02	24.11	5.26	7.01	16.90
268.80	18.90	8.27	0.147	2.24	1.97	22.65	5.06	6.76	15.77
252.00	18.40	8.26	0.153	2.17	1.97	24.23	5.48	6.62	14.77
235.20	17.80	8.31	0.164	2.07	1.94	22.72	5.28	6.43	13.66
218.40	17.30	8.40	0.175	2.02	1.95	21.77	5.23	6.19	12.76
201.60	16.70	8.53	0.187	1.91	1.91	20.35	5.06	5.87	11.72
184.80	16.10	8.96	0.201	1.80	1.86	20.36	5.18	5.67	10.66
168.00	15.60	8.97	0.214	1.68	1.80	19.10	5.01	5.32	9.86
151.20	15.10	9.04	0.229	1.58	1.75	18.04	4.92	5.16	9.09
134.40	14.60	9.16	0.244	1.49	1.69	17.04	4.83	4.91	8.32
117.60	14.10	7.85	0.261	1.38	1.64	15.90	4.69	4.59	7.57
100.80	13.60	8.03	0.280	1.28	1.57	14.75	4.51	4.26	6.85
84.00	13.10	8.22	0.302	1.16	1.47	13.57	4.29	4.01	6.13
67.20	5.70	7.44	0.330	1.04	1.38	12.65	4.17	3.93	5.44
50.40	5.40	12.19	0.462	1.46	2.00	12.37	4.28	5.48	4.04
33.60	5.00	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	5.00	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	5.00	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-37

BASIC BLADE DATA
C2 COMPOUND
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	23.65	6.97	0.081	1.87	1.38	19.90	3.80	5.90	9.55
410.40	23.65	19.60	0.162	3.75	2.92	39.80	7.80	12.70	19.20
388.80	23.65	14.51	0.183	4.20	3.24	42.90	8.50	15.00	19.40
367.20	23.65	15.77	0.204	4.75	3.62	53.00	9.80	14.90	19.73
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	24.10	13.20	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	9.71	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	9.71	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

DESIGN TWIST -8 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-38

BASIC BLADE DATA
C2 COMPOUND
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	7.88	6.97	0.180	0.27	0.39	3.83	1.59	1.10	2.13
410.40	11.82	19.60	0.361	0.55	0.78	1.66	3.19	2.20	4.27
388.80	15.76	14.51	0.287	1.51	1.60	17.13	5.30	5.34	8.98
367.20	19.70	15.77	0.249	3.03	2.56	35.24	8.24	10.60	14.90
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	24.10	13.20	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	9.71	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	9.71	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-39

BASIC BLADE DATA
C2 COMPOUND
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	15.80	6.97	0.113	0.89	0.86	10.11	2.82	2.95	5.80
410.40	17.40	19.60	0.226	1.79	1.72	20.22	5.64	5.90	11.61
388.80	18.90	14.51	0.232	2.48	2.18	26.48	6.77	8.36	14.06
367.20	20.50	15.77	0.239	3.35	2.73	38.58	8.66	11.63	16.35
345.60	22.00	15.74	0.229	4.24	3.21	47.11	9.92	14.43	19.10
324.00	23.70	17.14	0.216	5.45	3.83	65.10	12.45	19.09	22.37
302.40	25.30	10.29	0.204	6.62	4.35	76.43	13.63	22.44	26.07
280.80	26.80	17.63	0.196	7.66	4.76	86.88	14.70	25.83	29.29
259.20	28.50	17.02	0.194	8.30	5.03	92.99	15.35	27.91	31.00
237.60	30.00	18.04	0.180	10.40	5.78	113.00	17.07	34.13	37.43
216.00	31.60	17.71	0.173	11.90	6.28	127.60	18.35	39.16	41.84
194.40	33.20	16.61	0.167	13.65	6.84	143.90	19.67	44.39	46.60
172.80	34.70	16.42	0.164	14.84	7.20	155.30	20.58	48.29	49.93
151.20	36.40	16.42	0.157	17.31	7.93	177.70	22.23	56.03	56.39
129.60	37.90	17.33	0.155	19.25	8.44	200.20	23.82	62.41	61.65
108.00	16.20	18.46	0.167	26.92	11.36	246.50	28.26	77.42	66.44
86.40	16.90	38.11	0.193	117.70	46.59	486.30	54.83	294.40	72.42
64.80	16.90	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	16.90	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	16.90	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-40

BASIC BLADE DATA
C2 COMPOUND
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	27.00	6.97	0.072	2.40	1.51	25.14	4.59	7.48	14.68
410.40	26.40	19.60	0.144	4.80	3.03	50.29	9.19	14.97	29.36
388.80	25.70	14.51	0.168	5.08	3.29	51.26	9.65	16.43	27.54
367.20	25.00	15.77	0.192	5.41	3.61	59.81	10.98	18.21	25.57
345.60	24.40	15.74	0.205	5.44	3.71	59.22	11.22	18.23	24.11
324.00	23.60	17.14	0.217	5.39	3.81	64.50	12.38	18.91	22.16
302.40	22.90	10.29	0.228	5.16	3.75	60.77	12.04	17.74	20.63
280.80	22.30	17.63	0.239	4.91	3.67	57.84	11.79	17.03	19.34
259.20	21.60	17.02	0.252	4.62	3.57	54.45	11.48	16.13	17.95
237.60	21.00	18.04	0.265	4.40	3.50	51.39	11.15	15.24	16.76
216.00	20.30	17.71	0.281	4.09	3.36	47.98	10.81	14.40	15.43
194.40	19.60	16.61	0.297	3.79	3.22	44.63	10.42	13.40	14.11
172.80	18.90	16.42	0.316	3.46	3.05	41.18	10.00	12.42	12.88
151.20	18.20	16.42	0.336	3.16	2.89	37.89	9.58	11.54	11.64
129.60	17.50	17.33	0.365	2.80	2.66	35.11	9.18	10.53	10.42
108.00	7.00	18.46	0.434	2.97	2.93	35.09	9.55	10.59	90.37
86.40	6.70	38.11	0.710	3.50	3.60	28.04	8.69	23.93	44.19
64.80	6.70	124.62	3.000	100.00	25.00	100.00	25.00	100.00	100.00
43.20	6.70	77.12	3.000	100.00	25.00	100.00	25.00	150.00	100.00
24.00	6.70	84.59	3.000	100.00	25.00	100.00	25.00	150.00	100.00

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-41

BASIC BLADE DATA
C3 COMPOUND
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	18.25	2.27	0.072	0.98	0.92	10.30	2.50	2.90	12.94
319.20	18.25	10.99	0.146	1.96	1.84	20.50	5.00	5.90	12.94
302.40	18.25	8.88	0.148	2.00	1.88	20.70	5.10	6.02	12.98
285.60	18.25	8.40	0.151	2.02	1.90	20.90	5.10	6.15	13.00
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.31	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.213	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	6.80	5.00	37.80	8.60	20.00	14.85
33.60	8.10	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	8.10	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

DESIGN TWIST -2 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-42

BASIC BLADE DATA
C3 COMPOUND
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	6.08	2.27	0.161	0.12	0.22	1.87	0.89	0.49	1.25
319.20	9.12	10.99	0.332	0.24	0.44	3.73	1.77	0.99	2.50
302.40	12.16	8.88	0.233	0.69	0.95	8.19	2.89	2.29	5.62
285.60	15.20	8.40	0.184	1.29	1.42	13.94	3.91	3.98	9.65
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.38	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.203	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	6.80	5.00	37.80	8.60	20.00	14.85
33.60	8.10	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	8.10	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	8.10	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-43

BASIC BLADE DATA
C3 COMPOUND
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	12.20	2.27	0.100	0.45	0.56	5.13	1.63	1.41	3.59
319.20	13.40	10.99	0.210	0.90	1.12	10.25	3.26	2.83	7.18
302.40	14.60	8.88	0.190	1.15	1.32	12.61	3.69	3.59	8.79
285.60	15.80	8.40	0.180	1.42	1.50	15.21	4.10	4.36	10.55
268.80	17.00	8.27	0.170	1.74	1.71	17.98	4.47	5.32	12.45
252.00	18.20	8.26	0.160	2.12	1.94	23.66	5.41	6.46	14.41
235.20	19.40	8.31	0.150	2.54	2.19	27.42	5.84	7.80	16.56
218.40	20.70	8.40	0.140	3.09	2.49	32.21	6.46	9.28	19.05
201.60	22.00	8.53	0.140	3.69	2.79	37.17	6.99	10.92	21.70
184.80	23.20	8.96	0.140	4.34	3.12	45.41	7.98	12.98	24.23
168.00	24.40	8.97	0.130	4.94	3.38	51.04	8.52	14.69	26.99
151.20	25.60	9.04	0.130	5.68	3.70	57.66	9.22	17.15	29.88
134.40	26.80	9.16	0.130	6.53	4.06	65.18	9.99	19.66	32.89
117.60	28.00	7.85	0.120	7.51	4.47	73.16	10.77	22.25	36.03
100.80	29.20	8.03	0.120	8.71	4.97	82.90	11.68	25.40	39.28
84.00	30.40	8.22	0.120	9.96	5.46	92.90	12.49	29.33	42.66
67.20	14.00	7.44	0.120	11.46	6.04	105.80	13.72	35.34	46.19
50.40	14.50	12.19	0.140	28.51	14.48	138.30	17.37	65.76	49.14
33.60	15.00	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	15.00	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	15.00	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-44

BASIC BLADE DATA
C3 COMPOUND
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	21.00	2.27	0.064	1.29	1.05	13.29	2.73	3.78	9.54
319.20	20.60	10.99	0.128	2.59	2.10	26.58	5.46	7.57	19.09
302.40	20.10	8.88	0.134	2.50	2.07	25.48	5.40	7.43	18.08
285.60	19.50	8.40	0.140	2.36	2.02	24.11	5.26	7.01	16.90
268.80	18.90	8.27	0.147	2.24	1.97	22.65	5.06	6.76	15.77
252.00	18.40	8.26	0.153	2.17	1.97	24.23	5.48	6.62	14.77
235.20	17.80	8.31	0.164	2.07	1.94	22.72	5.28	6.43	13.66
218.40	17.30	8.40	0.175	2.02	1.95	21.77	5.23	6.19	12.76
201.60	16.70	8.53	0.187	1.91	1.91	20.35	5.06	5.87	11.72
184.80	16.10	8.96	0.201	1.80	1.86	20.36	5.18	5.67	10.66
168.00	15.60	8.97	0.214	1.68	1.80	19.10	5.01	5.32	9.86
151.20	15.10	9.04	0.229	1.58	1.75	18.04	4.92	5.16	9.09
134.40	14.60	9.16	0.244	1.49	1.69	17.04	4.83	4.91	8.32
117.60	14.10	7.85	0.261	1.38	1.64	15.90	4.69	4.59	7.57
100.80	13.60	8.03	0.280	1.28	1.57	14.75	4.51	4.26	6.85
84.00	13.10	8.22	0.302	1.16	1.47	13.57	4.29	4.01	6.13
67.20	5.70	7.44	0.330	1.04	1.38	12.65	4.17	3.93	5.44
50.40	5.40	12.19	0.462	1.46	2.00	12.37	4.28	5.48	4.04
33.60	5.00	69.17	1.500	50.00	15.00	70.00	10.00	35.00	50.00
16.80	5.00	71.84	2.000	75.00	18.00	75.00	15.00	100.00	100.00
12.63	5.00	14.80	2.000	75.00	18.00	75.00	15.00	100.00	100.00

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-45

BASIC BLADE DATA
C4 COMPOUND
1-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICKNESS (IN.)	FLATWISE IXX ($IN.^4$)	SECTION ZXX ($IN.^3$)	EDGEWISE IYY ($IN.^4$)	SECTION ZYY ($IN.^3$)	TORSION J ($IN.^4$)	MIDLINE AREA ($IN.^2$)
420.00	36.00	8.82	0.107	8.50	4.50	88.50	11.50	25.00	42.70
399.00	36.00	40.14	0.215	17.00	9.00	177.00	23.00	50.30	42.70
378.00	36.00	23.52	0.220	17.20	9.10	180.00	23.30	51.00	42.80
357.00	36.00	23.73	0.223	17.70	9.40	184.00	24.00	52.30	42.80
336.00	36.00	24.78	0.230	18.00	9.50	188.00	24.30	53.50	42.90
315.00	36.00	24.78	0.233	18.30	9.80	193.00	25.00	54.80	43.00
294.00	36.00	25.77	0.240	18.60	10.00	195.00	25.30	56.00	43.00
273.00	36.00	26.04	0.243	19.00	10.20	200.00	26.00	57.30	43.10
252.00	36.00	26.04	0.250	19.30	10.40	205.00	26.30	58.00	43.20
231.00	36.00	26.63	0.253	20.00	10.50	208.00	27.00	59.00	43.30
210.00	36.00	26.72	0.260	20.20	10.80	213.00	27.50	62.50	43.40
189.00	36.00	28.35	0.275	22.00	11.50	225.00	29.00	70.00	43.70
168.00	36.00	27.53	0.303	25.00	12.80	248.00	31.80	78.00	44.20
147.00	36.00	29.73	0.333	28.30	14.10	270.00	34.00	87.00	44.70
126.00	36.00	31.08	0.362	31.70	15.50	291.00	36.80	95.00	45.20
105.00	36.00	35.96	0.390	34.60	16.80	314.00	39.30	120.00	45.70
84.00	14.80	59.00	0.500	84.00	30.50	398.00	48.50	250.00	50.50
63.00	14.80	113.75	2.000	130.00	50.00	432.00	100.00	300.00	100.00
42.00	14.80	137.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00
30.00	14.80	52.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00

DESIGN TWIST -2 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-46

BASIC BLADE DATA
C4 COMPOUND
N.L. PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX (IN.^{4})	SEC-TION ZXX (IN.^{3})	EDGE-WISE IYY (IN.^{4})	SEC-TION ZYY (IN.^{3})	TOR-SION J (IN.^{4})	MID-LINE AREA (IN.^{2})
420.00	12.00	8.82	0.235	1.37	1.27	17.80	4.52	4.85	5.24
399.00	18.00	40.14	0.471	2.74	2.54	35.61	9.04	9.70	10.49
378.00	24.00	23.52	0.342	6.52	4.52	73.54	13.81	20.21	21.74
357.00	30.00	23.73	0.271	11.69	6.49	124.20	18.70	34.81	36.28
336.00	36.00	24.78	0.230	18.00	9.50	188.00	24.30	53.50	42.90
315.00	36.00	24.78	0.233	18.30	9.80	193.00	25.00	54.80	43.00
294.00	36.00	25.77	0.240	18.60	10.00	195.00	25.30	56.00	43.00
273.00	36.00	26.04	0.243	19.00	10.20	200.00	26.00	57.30	43.10
252.00	36.00	26.04	0.250	19.30	10.40	205.00	26.30	58.00	43.20
231.00	36.00	26.63	0.253	20.00	10.50	208.00	27.00	59.00	43.30
210.00	36.00	26.72	0.260	20.20	10.80	213.00	27.50	62.50	43.40
189.00	36.00	28.35	0.275	22.00	11.50	225.00	29.00	70.00	43.70
168.00	36.00	27.53	0.303	25.00	12.80	248.00	31.80	78.00	44.20
147.00	36.00	29.73	0.333	28.30	14.10	270.00	34.00	87.00	44.70
126.00	36.00	31.08	0.362	31.70	15.50	291.00	36.80	95.00	45.20
105.00	36.00	35.96	0.390	34.60	16.80	314.00	39.30	120.00	45.70
84.00	14.80	59.00	0.500	84.00	30.50	398.00	48.50	250.00	50.50
63.00	14.80	113.75	2.000	130.00	50.00	432.00	100.00	300.00	100.00
42.00	14.80	137.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00
30.00	14.80	52.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-47

BASIC BLADE DATA
C4 COMPOUND
3-1 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICKNESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SECTION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SECTION ZYY ($IN.^3$)	TORSION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
420.00	24.00	8.82	0.150	4.10	2.59	45.03	7.71	12.54	27.29
399.00	26.40	40.14	0.300	8.21	5.18	90.07	15.43	25.08	27.29
378.00	28.80	23.52	0.280	10.31	5.97	111.10	17.33	30.85	33.15
357.00	31.40	23.73	0.260	13.01	6.91	137.20	19.73	38.54	40.15
336.00	33.60	24.78	0.250	15.39	7.63	162.20	21.65	45.17	46.54
315.00	36.00	24.78	0.230	18.30	8.47	193.00	24.42	54.50	53.91
294.00	38.40	25.77	0.220	21.73	9.43	224.80	26.29	63.24	61.90
273.00	40.80	26.04	0.210	25.14	10.27	260.80	28.85	74.67	70.36
252.00	43.20	26.04	0.210	29.28	11.29	301.60	31.52	85.13	79.34
231.00	45.60	26.63	0.200	33.63	12.29	342.80	33.87	97.16	88.89
210.00	48.00	26.72	0.190	38.20	13.26	389.10	36.60	111.20	98.88
189.00	50.40	28.35	0.190	46.43	15.35	460.20	41.26	133.80	109.20
168.00	52.80	27.53	0.200	59.03	18.63	558.60	47.79	168.90	119.80
147.00	55.20	29.73	0.210	73.11	22.07	670.00	55.06	207.90	131.00
126.00	57.60	31.08	0.220	90.72	26.25	795.50	62.61	252.30	142.70
105.00	60.00	35.96	0.230	110.90	30.81	933.10	70.13	300.90	154.90
84.00	24.74	59.00	0.270	321.20	85.78	1361.00	95.19	633.30	163.60
63.00	24.74	113.75	2.000	130.00	50.00	432.00	100.00	300.00	100.00
42.00	24.74	137.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00
30.00	24.74	52.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-48

BASIC BLADE DATA
C4 COMPOUND
1-2 PLANFORM, ARTICULATED BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
420.00	41.00	8.82	0.096	10.79	4.48	111.10	12.48	31.50	68.31
399.00	40.10	40.14	0.192	21.58	8.97	222.20	24.96	63.00	68.31
378.00	39.10	23.52	0.202	20.79	8.86	214.40	24.57	60.31	64.65
357.00	38.10	23.73	0.210	20.20	8.84	207.50	24.56	58.76	61.12
336.00	37.10	24.78	0.223	19.26	8.65	200.40	24.20	56.03	57.68
315.00	36.10	24.78	0.232	18.41	8.50	194.10	24.50	54.83	54.24
294.00	34.90	25.77	0.248	17.52	8.37	183.40	23.61	51.40	50.35
273.00	33.90	26.04	0.259	16.56	8.14	175.80	23.43	49.97	47.15
252.00	32.90	26.04	0.274	15.84	8.02	168.80	23.22	47.16	44.04
231.00	31.90	26.63	0.288	15.02	7.85	160.10	22.68	44.77	41.08
210.00	30.90	26.72	0.306	14.11	7.61	152.00	22.29	42.71	38.12
189.00	29.70	28.35	0.339	13.88	7.79	148.00	22.62	42.15	34.52
168.00	28.70	27.53	0.391	14.37	8.34	149.50	23.68	44.05	31.39
147.00	27.60	29.73	0.446	14.26	8.61	147.60	24.46	44.40	28.10
126.00	26.60	31.08	0.510	14.16	8.88	144.90	24.94	44.33	25.16
105.00	25.60	35.96	0.581	13.68	8.91	139.70	24.91	43.28	22.31
84.00	10.60	59.00	0.828	19.52	13.22	136.40	24.80	62.85	15.50
63.00	10.60	113.75	2.000	130.00	50.00	432.00	100.00	300.00	100.00
42.00	10.60	137.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00
30.00	10.60	52.50	3.000	150.00	50.00	500.00	150.00	300.00	150.00

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-49

BASIC BLADE DATA
C1-R COMPOUND
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	18.25	2.27	0.072	0.98	0.92	10.30	2.50	2.90	12.94
319.20	18.25	10.99	0.146	1.96	1.84	20.50	5.00	5.90	12.94
302.40	18.25	8.88	0.148	2.00	1.88	20.70	5.10	6.02	12.98
285.60	18.25	8.40	0.151	2.02	1.90	20.90	5.10	6.15	13.00
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.31	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.213	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	5.00	3.00	23.00	6.00	20.00	14.85
33.60	8.10	69.17	1.500	5.00	3.00	23.00	6.00	35.00	50.00
16.80	8.10	71.84	2.000	5.00	3.00	23.00	6.00	100.00	100.00
12.63	8.10	14.80	2.000	5.00	3.00	23.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.42 DEG. AT 0 DEG DESIGN TWIST PRELAG ANGLE -4.12 DEG

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-50

BASIC BLADE DATA
C1-R COMPOUND
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	6.08	2.27	0.161	0.12	0.22	1.87	0.89	0.49	1.25
319.20	9.12	10.99	0.332	0.24	0.44	3.73	1.77	0.99	2.50
302.40	12.16	8.88	0.233	0.69	0.95	8.19	2.89	2.29	5.62
285.60	15.20	8.40	0.184	1.29	1.42	13.94	3.91	3.98	9.65
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.38	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	9.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.203	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	5.00	3.00	23.00	6.00	20.00	14.85
33.60	8.10	69.17	1.500	5.00	3.00	23.00	6.00	35.00	50.00
16.80	8.10	71.84	2.000	5.00	3.00	23.00	6.00	100.00	100.00
12.63	8.10	14.80	2.000	5.00	3.00	23.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.45 DEG. AT 0 DEG TWIST PRELAG ANGLE -3.3 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-51

BASIC BLADE DATA
C1-R COMPOUND
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	12.20	2.27	0.100	0.45	0.56	5.13	1.63	1.41	3.59
319.20	13.40	10.99	0.210	0.90	1.12	10.25	3.26	2.83	7.18
302.40	14.60	8.88	0.190	1.15	1.32	12.61	3.69	3.59	8.79
285.60	15.80	8.40	0.180	1.42	1.50	15.21	4.10	4.36	10.55
268.80	17.00	8.27	0.170	1.74	1.71	17.98	4.47	5.32	12.45
252.00	18.20	8.26	0.160	2.12	1.94	23.66	5.41	6.46	14.41
235.20	19.40	8.31	0.150	2.54	2.19	27.42	5.84	7.80	16.56
218.40	20.70	8.40	0.140	3.09	2.49	32.21	6.46	9.28	19.05
201.60	22.00	8.53	0.140	3.69	2.79	37.17	6.99	10.92	21.70
184.80	23.20	8.96	0.140	4.34	3.12	45.41	7.98	12.98	24.23
168.00	24.40	8.97	0.130	4.94	3.38	51.04	8.52	14.69	26.99
151.20	25.60	9.04	0.130	5.68	3.70	57.66	9.22	17.15	29.88
134.40	26.80	9.16	0.130	6.53	4.06	65.18	9.99	19.66	32.89
117.60	28.00	7.85	0.120	7.51	4.47	73.16	10.77	22.25	36.03
100.80	29.20	8.03	0.120	8.71	4.97	82.90	11.68	25.40	39.28
84.00	30.40	8.22	0.120	9.96	5.46	92.90	12.49	29.33	42.66
67.20	14.00	7.44	0.120	11.46	6.04	105.80	13.72	35.34	46.19
50.40	14.50	12.19	0.140	28.51	14.48	18.00	10.00	65.76	49.14
33.60	15.00	69.17	1.500	30.00	15.00	18.00	10.00	35.00	50.00
16.80	15.00	71.84	2.000	30.00	15.00	18.00	10.00	100.00	100.00
12.63	15.00	14.80	2.000	30.00	15.00	18.00	10.00	100.00	100.00

BEARING FLEXIBILITY 10 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.47 DEG. AT 0 DEG TWIST PRELAG ANGLE -3.62 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE 8-52

BASIC BLADE DATA
C1-R COMPOUND
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 12,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	21.00	2.27	0.064	1.29	1.05	13.29	2.73	3.78	9.54
319.20	20.60	10.99	0.128	2.59	2.10	26.58	5.46	7.57	19.09
302.40	20.10	8.88	0.134	2.50	2.07	25.48	5.40	7.43	18.08
285.60	19.50	8.40	0.140	2.36	2.02	24.11	5.26	7.01	16.90
268.80	18.90	8.27	0.147	2.24	1.97	22.65	5.06	6.76	15.77
252.00	18.40	8.26	0.153	2.17	1.97	24.23	5.48	6.62	14.77
235.20	17.80	8.31	0.164	2.07	1.94	22.72	5.28	6.43	13.66
218.40	17.30	8.40	0.175	2.02	1.95	21.77	5.23	6.19	12.76
201.60	16.70	8.53	0.187	1.91	1.91	20.35	5.06	5.87	11.72
184.80	16.10	8.96	0.201	1.80	1.86	20.36	5.18	5.67	10.66
168.00	15.60	8.97	0.214	1.68	1.80	19.10	5.01	5.32	9.86
151.20	15.10	9.04	0.229	1.58	1.75	18.04	4.92	5.16	9.09
134.40	14.60	9.16	0.244	1.49	1.69	17.04	4.83	4.91	8.32
117.60	14.10	7.85	0.261	1.38	1.64	15.90	4.69	4.59	7.57
100.80	13.60	8.03	0.280	1.28	1.57	14.75	4.51	4.26	6.85
84.00	13.10	8.22	0.302	1.16	1.47	13.57	4.29	4.01	6.13
67.20	5.70	7.44	0.330	1.04	1.38	12.65	4.17	3.93	5.44
50.40	5.40	12.19	0.462	1.46	2.00	40.00	10.00	5.48	4.04
33.60	5.00	69.17	1.500	4.00	3.00	40.00	10.00	35.00	50.00
16.80	5.00	71.84	2.000	4.00	3.00	40.00	10.00	100.00	100.00
12.63	5.00	14.80	2.000	4.00	3.00	40.00	10.00	100.00	100.00

BEARING FLEXIBILITY 12 MILLION IN.LB. PER RAD.

PRECONE ANGLE 2.38 DEG. AT 0 DEG TWIST PRELAG ANGLE -4.37 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-53

BASIC BLADE DATA
C2-R COMPOUND
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX $(IN.^4)$	SEC-TION ZXX $(IN.^3)$	EDGE-WISE IYY $(IN.^4)$	SEC-TION ZYY $(IN.^3)$	TOR-SION J $(IN.^4)$	MID-LINE AREA $(IN.^2)$
432.00	23.65	6.97	0.081	1.87	1.38	19.90	3.80	5.90	9.55
410.40	23.65	19.60	0.162	3.75	2.92	39.80	7.80	12.70	19.20
388.80	23.65	14.51	0.183	4.20	3.24	42.90	8.50	15.00	19.40
367.20	23.65	15.77	0.204	4.75	3.62	53.00	9.80	14.90	19.73
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	10.00	6.00	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	10.00	7.00	43.00	10.00	100.00	100.00
43.20	9.71	77.12	3.000	10.00	7.00	43.00	10.00	150.00	100.00
24.00	9.71	84.59	3.000	10.00	7.00	43.00	10.00	150.00	100.00

BEARING FLEXIBILITY 20 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.4 DEG. AT 0 DEG DESIGN TWIST PRELAG ANGLE -4.09 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-54

BASIC BLADE DATA
C2-R COMPOUND
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	7.88	6.97	0.180	0.27	0.39	3.83	1.59	1.10	2.13
410.40	11.82	19.60	0.361	0.55	0.78	7.66	3.19	2.20	4.27
388.80	15.76	14.51	0.287	1.51	1.60	17.13	5.30	5.34	8.98
367.20	19.70	15.77	0.249	3.03	2.56	35.24	8.24	10.60	14.90
345.60	23.65	15.74	0.212	5.05	3.80	55.30	10.20	16.55	19.86
324.00	23.65	17.14	0.216	5.42	4.15	64.80	11.30	18.00	20.12
302.40	23.65	10.29	0.221	5.58	4.20	65.30	11.45	19.05	20.15
280.80	23.65	17.63	0.224	5.68	4.28	66.00	11.60	19.30	20.20
259.20	23.65	17.02	0.228	5.80	4.35	66.80	11.70	19.70	20.23
237.60	23.65	18.04	0.232	5.95	4.40	67.30	11.90	20.00	20.28
216.00	23.65	17.71	0.237	6.05	4.48	68.00	12.00	20.30	20.30
194.40	23.65	16.61	0.241	6.18	4.55	68.80	12.10	20.75	20.36
172.80	23.65	16.42	0.245	6.25	4.60	69.30	12.30	21.05	20.40
151.20	23.65	16.42	0.249	6.40	4.70	70.10	12.40	21.40	20.43
129.60	23.65	17.33	0.258	6.45	4.90	72.00	12.80	21.85	20.57
108.00	9.71	18.46	0.290	8.10	5.80	80.80	14.30	23.40	21.00
86.40	9.71	38.11	0.375	10.00	6.00	124.00	22.20	48.80	24.60
64.80	9.71	124.62	3.000	10.00	7.00	43.00	10.00	100.00	100.00
43.20	9.71	77.12	3.000	10.00	7.00	43.00	10.00	150.00	100.00
24.00	9.71	84.59	3.000	10.00	7.00	43.00	10.00	150.00	100.00

BEARING FLEXIBILITY 20 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.38 DEG. AT 0 DEG TWIST PRELAG ANGLE -3.35 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-55

BASIC BLADE DATA
C2-R COMPOUND
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	15.80	6.97	0.113	0.89	0.86	10.11	2.82	2.95	5.80
410.40	17.40	19.60	0.226	1.79	1.72	20.22	5.64	5.90	11.61
388.80	18.90	14.51	0.232	2.48	2.18	26.48	6.77	8.36	14.06
367.20	20.50	15.77	0.239	3.35	2.73	38.58	8.66	11.63	16.35
345.60	22.00	15.74	0.229	4.24	3.21	47.11	9.92	14.43	19.10
324.00	23.70	17.14	0.216	5.45	3.83	65.10	12.45	19.09	22.37
302.40	25.30	10.29	0.204	6.62	4.35	76.43	13.63	22.44	26.07
280.80	26.80	17.63	0.196	7.66	4.76	86.88	14.70	25.83	29.29
259.20	28.50	17.02	0.194	8.30	5.03	92.99	15.35	27.91	31.00
237.60	30.00	18.04	0.180	10.40	5.78	113.00	17.07	34.13	37.43
216.00	31.60	17.71	0.173	11.90	6.28	127.60	18.35	39.16	41.84
194.40	33.20	16.61	0.167	13.65	6.84	143.90	19.67	44.39	46.60
172.80	34.70	16.42	0.164	14.84	7.20	155.30	20.58	48.29	49.93
151.20	36.40	16.42	0.157	17.31	7.93	177.70	22.23	56.03	56.39
129.60	37.90	17.33	0.155	19.25	8.44	200.20	23.82	62.41	61.65
108.00	16.20	18.46	0.167	26.92	11.36	246.50	28.26	77.42	66.44
86.40	16.90	38.11	0.193	35.00	15.00	486.30	54.83	294.40	72.42
64.80	16.90	124.62	3.000	50.00	13.00	34.00	10.00	100.00	100.00
43.20	16.90	77.12	3.000	50.00	13.00	34.00	10.00	150.00	100.00
24.00	16.90	84.59	3.000	50.00	13.00	34.00	10.00	150.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.59 DEG. AT 0 DEG TWIST PRELAG ANGLE -3.66 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-56

BASIC BLADE DATA
C2-R COMPOUND
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 27,000 LB., 200-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
432.00	27.00	6.97	0.072	2.40	1.51	25.15	4.59	7.48	14.68
410.40	26.40	19.60	0.144	4.80	3.03	50.29	9.19	14.97	29.36
388.80	25.70	14.51	0.168	5.08	3.29	51.26	9.65	16.43	27.54
367.20	25.00	15.77	0.192	5.41	3.61	59.81	10.98	18.21	25.57
345.60	24.40	15.74	0.205	5.44	3.71	59.22	11.22	18.23	24.11
324.00	23.60	17.14	0.217	5.39	3.81	64.50	12.38	18.91	22.16
302.40	22.90	10.29	0.228	5.16	3.75	60.77	12.04	17.74	20.63
280.80	22.30	17.63	0.239	4.91	3.67	57.84	11.79	17.03	19.34
259.20	21.60	17.02	0.252	4.62	3.57	54.45	11.48	16.13	17.95
237.60	21.00	18.04	0.265	4.40	3.50	51.39	11.15	15.24	16.76
216.00	20.30	17.71	0.281	4.09	3.36	47.98	10.81	14.40	15.43
194.40	19.60	16.61	0.297	3.79	3.22	44.63	10.42	13.40	14.11
172.80	18.90	16.42	0.316	3.46	3.05	41.18	10.00	12.42	12.88
151.20	18.20	16.42	0.336	3.16	2.89	37.89	9.58	11.54	11.64
129.60	17.50	17.33	0.365	2.80	2.66	35.11	9.18	10.53	10.42
108.00	7.00	18.46	0.434	2.97	2.93	35.09	9.55	10.59	90.37
86.40	6.70	38.11	0.710	3.50	3.60	28.04	8.69	23.93	44.19
64.80	6.70	124.62	3.000	10.00	7.00	60.00	10.00	100.00	100.00
43.20	6.70	77.12	3.000	10.00	7.00	60.00	10.00	150.00	100.00
24.00	6.70	84.59	3.000	10.00	7.00	60.00	10.00	150.00	100.00

BEARING FLEXIBILITY 15 MILLION IN.LB. PER RAD.

PRECONE ANGLE 3.25 DEG. AT 0 DEG TWIST PRELAG ANGLE -4.26 DEG.

TWIST VARIATIONS +4, 0, -4, -8 DEG.

TABLE B-57

BASIC BLADE DATA
C3-R COMPOUND
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICKNESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SECTION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SECTION ZYY ($IN.^3$)	TORSION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	18.25	2.27	0.072	0.98	0.92	10.30	2.50	2.90	12.94
319.20	18.25	10.99	0.146	1.96	1.84	20.50	5.00	5.90	12.94
302.40	18.25	8.88	0.148	2.00	1.88	20.70	5.10	6.02	12.98
285.60	18.25	8.40	0.151	2.02	1.90	20.90	5.10	6.15	13.00
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.31	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.213	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	5.00	3.00	23.00	6.00	20.00	14.85
33.60	8.10	69.17	1.500	5.00	3.00	23.00	6.00	35.00	50.00
16.80	8.10	71.84	2.000	5.00	3.00	23.00	6.00	100.00	100.00
12.63	8.10	14.80	2.000	5.00	3.00	23.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 0.76 DEG. AT -2 DEG DESIGN TWIST PRELAG ANGLE -3.38 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-58

BASIC BLADE DATA
C3-R COMPOUND
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	6.08	2.27	0.161	0.12	0.22	1.87	0.89	0.49	1.25
319.20	9.12	10.99	0.332	0.24	0.44	3.73	1.77	0.99	2.50
302.40	12.16	8.88	0.233	0.69	0.95	8.19	2.89	2.29	5.62
285.60	15.20	8.40	0.184	1.29	1.42	13.94	3.91	3.98	9.65
268.80	18.25	8.27	0.153	2.06	1.92	21.00	5.20	6.30	13.00
252.00	18.25	8.26	0.155	2.13	2.00	23.80	5.50	6.65	13.12
235.20	18.25	8.31	0.160	2.20	2.03	24.00	5.60	6.90	13.16
218.40	18.25	8.40	0.165	2.30	2.14	24.50	5.70	7.10	13.20
201.60	18.25	8.53	0.170	2.38	2.20	24.80	5.80	7.40	13.25
184.80	18.25	8.96	0.175	2.47	2.26	27.00	6.10	7.65	13.35
168.00	18.25	8.97	0.180	2.51	2.30	27.25	6.20	7.90	13.38
151.20	18.25	9.04	0.185	2.59	2.36	27.80	6.20	8.25	13.40
134.40	18.25	9.16	0.190	2.68	2.40	28.50	6.40	8.50	13.45
117.60	18.25	7.85	0.195	2.78	2.50	29.00	6.50	8.70	13.50
100.80	18.25	8.03	0.200	2.88	2.60	29.50	6.70	9.00	13.55
84.00	18.25	8.22	0.206	2.97	2.65	30.00	6.80	9.60	13.60
67.20	8.10	7.44	0.203	3.10	2.75	31.20	7.10	14.00	13.72
50.40	8.10	12.19	0.273	5.00	3.00	23.00	6.00	20.00	14.85
33.60	8.10	69.17	1.500	5.00	3.00	23.00	6.00	35.00	50.00
16.80	8.10	71.84	2.000	5.00	3.00	23.00	6.00	100.00	100.00
12.63	8.10	14.80	2.000	5.00	3.00	23.00	6.00	100.00	100.00

BEARING FLEXIBILITY 9 MILLION IN.LB. PER RAD.

PRECONE ANGLE 0.79 DEG. AT -2 DEG TWIST PRELAG ANGLE -2.37 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-59

BASIC BLADE DATA
C3-R COMPOUND
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX (IN.^{4})	SEC-TION ZXX (IN.^{3})	EDGE-WISE IYY (IN.^{4})	SEC-TION ZYY (IN.^{3})	TOR-SION J (IN.^{4})	MID-LINE AREA (IN.^{2})
336.00	12.20	2.27	0.100	0.45	0.56	5.13	1.63	1.41	3.59
319.20	13.40	10.99	0.210	0.90	1.12	10.25	3.26	2.83	7.18
302.40	14.60	8.88	0.190	1.15	1.32	12.61	3.69	3.59	8.79
285.60	15.80	8.40	0.180	1.42	1.50	15.21	4.10	4.36	10.55
268.80	17.00	8.27	0.170	1.74	1.71	17.98	4.47	5.32	12.45
252.00	18.20	8.26	0.160	2.12	1.94	23.66	5.41	6.46	14.41
235.20	19.40	8.31	0.150	2.54	2.19	27.42	5.84	7.80	16.56
218.40	20.70	8.40	0.140	3.09	2.49	32.21	6.46	9.28	19.05
201.60	22.00	8.53	0.140	3.69	2.79	37.17	6.99	10.92	21.70
184.80	23.20	8.96	0.140	4.34	3.12	45.41	7.98	12.98	24.23
168.00	24.40	8.97	0.130	4.94	3.38	51.04	8.52	14.69	26.99
151.20	25.60	9.04	0.130	5.68	3.70	57.66	9.22	17.15	29.88
134.40	26.80	9.16	0.130	6.53	4.06	65.18	9.99	19.66	32.89
117.60	28.00	7.85	0.120	7.51	4.47	73.16	10.77	22.25	36.03
100.80	29.20	8.03	0.120	8.71	4.97	82.90	11.68	25.40	39.28
84.00	30.40	8.22	0.120	9.96	5.46	92.90	12.49	29.33	42.66
67.20	14.00	7.44	0.120	11.46	6.04	105.80	13.72	35.34	46.19
50.40	14.50	12.19	0.140	28.51	14.48	18.00	10.00	65.76	49.14
33.60	15.00	69.17	1.500	30.00	15.00	18.00	10.00	35.00	50.00
16.80	15.00	71.84	2.000	30.00	15.00	18.00	10.00	100.00	100.00
12.63	15.00	14.80	2.000	30.00	15.00	18.00	10.00	100.00	100.00

BEARING FLEXIBILITY 10 MILLION IN.LB. PER RAD.

PRECONE ANGLE 1.00 DEG. AT -2 DEG TWIST PRELAG ANGLE -2.80 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-60

BASIC BLADE DATA
C3-R COMPOUND
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 14,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
336.00	21.00	2.27	0.064	1.29	1.05	13.29	2.73	3.78	9.54
319.20	20.60	10.99	0.128	2.59	2.10	26.58	5.46	7.57	19.09
302.40	20.10	8.88	0.134	2.50	2.07	25.48	5.40	7.43	18.08
285.60	19.50	8.40	0.140	2.36	2.02	24.11	5.26	7.01	16.90
268.80	18.90	8.27	0.147	2.24	1.97	22.65	5.06	6.76	15.77
252.00	18.40	8.26	0.153	2.17	1.97	24.23	5.48	6.62	14.77
235.20	17.80	8.31	0.164	2.07	1.94	22.72	5.28	6.43	13.66
218.40	17.30	8.40	0.175	2.02	1.95	21.77	5.23	6.19	12.76
201.60	16.70	8.53	0.187	1.91	1.91	20.35	5.06	5.87	11.72
184.80	16.10	8.96	0.201	1.80	1.86	20.36	5.18	5.67	10.66
168.00	15.60	8.97	0.214	1.68	1.80	19.10	5.01	5.32	9.86
151.20	15.10	9.04	0.229	1.58	1.75	18.04	4.92	5.16	9.09
134.40	14.60	9.16	0.244	1.49	1.69	17.04	4.83	4.91	8.32
117.60	14.10	7.85	0.261	1.38	1.64	15.90	4.69	4.59	7.57
100.80	13.60	8.03	0.280	1.28	1.57	14.75	4.51	4.26	6.85
84.00	13.10	8.22	0.302	1.16	1.47	13.57	4.29	4.01	6.13
67.20	5.70	7.44	0.330	1.04	1.38	12.65	4.17	3.93	5.44
50.40	5.40	12.19	0.462	1.46	2.00	40.00	10.00	5.48	4.04
33.60	5.00	69.17	1.500	4.00	3.00	40.00	10.00	35.00	50.00
16.80	5.00	71.84	2.000	4.00	3.00	40.00	10.00	100.00	100.00
12.63	5.00	14.80	2.000	4.00	3.00	40.00	10.00	100.00	100.00

BEARING FLEXIBILITY 12 MILLION IN.LB. PER RAD.

PRECONE ANGLE 0.67 DEG. AT -2 DEG TWIST PRELAG ANGLE -3.53 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-61

BASIC BLADE DATA
C4-R COMPOUND
1-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
420.00	36.00	8.82	0.107	8.50	4.50	88.50	11.50	25.00	42.70
399.00	36.00	40.14	0.215	17.00	9.00	177.00	23.00	50.30	42.70
378.00	36.00	23.52	0.220	17.20	9.10	180.00	23.30	51.00	42.80
357.00	36.00	23.73	0.223	17.70	9.40	184.00	24.00	52.30	42.80
336.00	36.00	24.78	0.230	18.00	9.50	188.00	24.30	53.50	42.90
315.00	36.00	24.78	0.233	18.30	9.80	193.00	25.00	54.80	43.00
294.00	36.00	25.77	0.240	18.60	10.00	195.00	25.30	56.00	43.00
273.00	36.00	26.04	0.243	19.00	10.20	200.00	26.00	57.30	43.10
252.00	36.00	26.04	0.250	19.30	10.40	205.00	26.30	58.00	43.20
231.00	36.00	26.63	0.253	20.00	10.50	208.00	27.00	59.00	43.30
210.00	36.00	26.72	0.260	20.20	10.80	213.00	27.50	62.50	43.40
189.00	36.00	28.35	0.275	22.00	11.50	225.00	29.00	70.00	43.70
168.00	36.00	27.53	0.303	25.00	12.80	248.00	31.80	78.00	44.20
147.00	36.00	29.73	0.333	28.30	14.10	270.00	34.00	87.00	44.70
126.00	36.00	31.08	0.362	31.70	15.50	291.00	36.80	95.00	45.20
105.00	36.00	35.96	0.390	34.60	16.80	314.00	39.30	120.00	45.70
84.00	14.80	59.00	0.500	84.00	30.50	398.00	48.50	250.00	50.50
63.00	14.80	113.75	2.000	107.00	40.00	432.00	100.00	300.00	100.00
42.00	14.80	137.50	3.000	107.00	40.00	432.00	100.00	300.00	150.00
30.00	14.80	52.50	3.000	107.00	40.00	432.00	100.00	300.00	150.00

CANTILEVERED ROOT RESTRAINT

PRECONE ANGLE 0.80 DEG. AT -2 DEG DESIGN TWIST PRELAG ANGLE -1.80 DE

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-62

BASIC BLADE DATA
C4-R COMPOUND
N.L. PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
420.00	12.00	8.82	0.235	1.37	1.27	17.80	4.52	4.85	5.24
399.00	18.00	40.14	0.471	2.74	2.54	35.61	9.04	9.70	10.49
378.00	24.00	23.52	0.342	6.52	4.52	73.54	13.81	20.21	21.74
357.00	30.00	23.73	0.271	11.69	6.49	124.20	18.70	34.81	36.28
336.00	36.00	24.78	0.230	18.00	9.50	188.00	24.30	53.50	42.90
315.00	36.00	24.78	0.233	18.30	9.80	193.00	25.00	54.80	43.00
294.00	36.00	25.77	0.240	18.60	10.00	195.00	25.30	56.00	43.00
273.00	36.00	26.04	0.243	19.00	10.20	200.00	26.00	57.30	43.10
252.00	36.00	26.04	0.250	19.30	10.40	205.00	26.30	58.00	43.20
231.00	36.00	26.63	0.253	20.00	10.50	208.00	27.00	59.00	43.30
210.00	36.00	26.72	0.260	20.20	10.80	213.00	27.50	62.50	43.40
189.00	36.00	28.35	0.275	22.00	11.50	225.00	29.00	70.00	43.70
168.00	36.00	27.53	0.303	25.00	12.80	248.00	31.80	78.00	44.20
147.00	36.00	29.73	0.333	28.30	14.10	270.00	34.00	87.00	44.70
126.00	36.00	31.08	0.362	31.70	15.50	291.00	36.80	95.00	45.20
105.00	36.00	35.96	0.390	34.60	16.80	314.00	39.30	120.00	45.70
84.00	14.80	59.00	0.500	84.00	30.50	398.00	48.50	250.00	50.50
63.00	14.80	113.75	2.000	107.00	40.00	432.00	100.00	300.00	100.00
42.00	14.80	137.50	3.000	107.00	40.00	432.00	100.00	300.00	150.00
30.00	14.80	52.50	3.000	107.00	40.00	432.00	100.00	300.00	150.00

CANTILEVERED ROOT RESTRAINT

PRECONE ANGLE 0.80 DEG. AT -2 DEG TWIST PRELAG ANGLE -1.31 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-63

BASIC BLADE DATA
C4-R COMPOUND
3-1 PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
420.00	24.00	8.82	0.150	4.10	2.59	45.03	7.71	12.54	27.29
399.00	26.40	40.14	0.300	8.21	5.18	90.07	15.43	25.08	27.29
378.00	28.80	23.52	0.280	10.31	5.97	111.10	17.33	30.85	33.15
357.00	31.40	23.73	0.260	13.01	6.91	137.20	19.73	38.54	40.15
336.00	33.60	24.78	0.250	15.39	7.63	162.20	21.65	45.17	46.54
315.00	36.00	24.78	0.230	18.30	8.47	193.00	24.42	54.50	53.91
294.00	38.40	25.77	0.220	21.73	9.43	224.80	26.29	63.24	61.90
273.00	40.80	26.04	0.210	25.14	10.27	260.80	28.85	74.67	70.36
252.00	43.20	26.04	0.210	29.28	11.29	301.60	31.52	85.13	79.34
231.00	45.60	26.63	0.200	33.63	12.29	342.80	33.87	97.16	88.89
210.00	48.00	26.72	0.190	38.20	13.26	389.10	36.60	111.20	98.88
189.00	50.40	28.35	0.190	46.43	15.35	460.20	41.26	133.80	109.20
168.00	52.80	27.53	0.200	59.03	18.63	558.60	47.79	168.90	119.80
147.00	55.20	29.73	0.210	73.11	22.07	670.00	55.06	207.90	131.00
126.00	57.60	31.08	0.220	90.72	26.25	795.50	62.61	252.30	142.70
105.00	60.00	35.96	0.230	110.90	30.81	933.10	70.13	300.90	154.90
84.00	24.74	59.00	0.270	321.20	85.78	1361.00	95.19	633.30	163.60
63.00	24.74	113.75	2.000	180.00	60.00	330.00	50.00	300.00	100.00
42.00	24.74	137.50	3.000	180.00	60.00	330.00	50.00	300.00	150.00
30.00	24.74	52.50	3.000	180.00	60.00	330.00	50.00	300.00	150.00

CANTILEVERED ROOT RESTRAINT

PRECONE ANGLE 0.93 DEG. AT -2 DEG TWIST PRELAG ANGLE -1.60 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

TABLE B-64

BASIC BLADE DATA
C4-R COMPOUND
1-2 PLANFORM, RIGID BLADE
GROSS WEIGHT 30,000 LB., 250-KNOT DESIGN

RADII (IN.)	CHORD (IN.)	SEGMENT WEIGHT (LB.)	WALL THICK-NESS (IN.)	FLAT-WISE IXX ($IN.^4$)	SEC-TION ZXX ($IN.^3$)	EDGE-WISE IYY ($IN.^4$)	SEC-TION ZYY ($IN.^3$)	TOR-SION J ($IN.^4$)	MID-LINE AREA ($IN.^2$)
420.00	41.00	8.82	0.096	10.79	4.48	111.10	12.48	31.50	68.31
399.00	40.10	40.14	0.192	21.58	8.97	222.20	24.96	63.00	68.31
378.00	39.10	23.52	0.202	20.79	8.86	214.40	24.57	60.31	64.65
357.00	38.10	23.73	0.210	20.20	8.84	207.50	24.56	58.76	61.12
336.00	37.10	24.78	0.223	19.26	8.65	200.40	24.20	56.03	57.68
315.00	36.10	24.78	0.232	18.41	8.50	194.10	24.50	54.83	54.24
294.00	34.90	25.77	0.248	17.52	8.37	183.40	23.61	51.40	50.35
273.00	33.90	26.04	0.259	16.56	8.14	175.80	23.43	49.97	47.15
252.00	32.90	26.04	0.274	15.84	8.02	168.80	23.22	47.16	44.04
231.00	31.90	26.63	0.288	15.02	7.85	160.10	22.68	44.77	41.08
210.00	30.90	26.72	0.306	14.11	7.61	152.00	22.29	42.71	38.12
189.00	29.70	28.35	0.339	13.88	7.79	148.00	22.62	42.15	34.52
168.00	28.70	27.53	0.391	14.37	8.35	149.50	23.68	44.05	31.39
147.00	27.60	29.73	0.446	14.26	8.61	147.60	24.46	44.40	28.10
126.00	26.60	31.08	0.510	14.16	8.88	144.90	24.94	44.33	25.16
105.00	25.60	35.96	0.581	13.68	8.91	139.70	24.91	43.28	22.31
84.00	10.60	59.00	0.828	19.52	13.22	136.40	24.80	62.85	15.50
63.00	10.60	113.75	2.000	40.00	18.00	57.00	25.00	300.00	100.00
42.00	10.60	137.50	3.000	40.00	18.00	57.00	25.00	300.00	150.00
30.00	10.60	52.50	3.000	40.00	18.00	57.00	25.00	300.00	150.00

BEARING FLEXIBILITY 20 MILLION IN.LB. PER RAD.

PRECONE ANGLE 0.70 DEG. AT -2 DEG TWIST PRELAG ANGLE -1.87 DEG.

TWIST VARIATIONS +2, 0, -2, -4 DEG.

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